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SIMULATION OF HYDRAZINE-DRIVEN EMERGENCY POWER GENERATOR

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The result of this study is a computer program which simulates the performance of a turbo-alternator power system under varying load conditions. The propellant used in this model is hydrazine and the design output level of the alternator is 3mw.

The computer program uses the technique of Newton-Raphson for the

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Block 20 (continued)

simultaneous solution of non-linear equations. The program is set up to allow easy modification to the system equations.

The decomposition chamber, turbine stages, and exhaust system are the main components simulated in the program. The decomposition chamber equations are based upon experimental data determined by United Aircraft Corporation using Shell 405 catalyst. The remaining system equations were determined using basic thermodynamic and fluid dynamic relationships. Certain energy loss equations were used for the turbine stages which were also empirically determined.

FOREWORD

This manuscript was prepared by David W. Williams under Grant No. DACA 88-73-A-002 as a reimbursable task for the Advanced Ballistic Missile Defense Agency (ABMDA), (IAO CE-CERL 72-1). The program was carried out under a grant to the University of Illinois, Champaign-Urbana, while the author was working toward a Master of Science degree in Mechanical Engineering.

Assistance and guidance on the project were provided by Dr. J. J. Burns and Dr. N. R. Moore, both of the U.S. Construction Engineering Research Laboratory (CERL). COL R. W. Reisacher is Director of CERL and Dr. L. R. Shaffer is Deputy Director.

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1. INTRODUCTION

1.1 Objective

The overall objective of this project is to develop a computer code which simulates the performance characteristics of a hydrazine-driven, turbo-alternator power system with operating time (propellant storage capacity), type of propellant, and power output as independent variables. Within the scope of this part of the project, operating time (two hours) and type of propellant (hydrazine) remained fixed. Power output was the system independent variable and the effects of varying power output on the entire system were investigated.

1.2 Explanation of Problem and Approach

The turbo-alternator power system consists of a small, multi-stage, gas turbine which drives a high rotational speed alternator. Schematic and pictorial diagrams are shown in Figs. 1 and 2, respectively. Preliminary calculations and available data indicated that a turbine powered with the products of catalytic decomposition of liquid hydrazine has certain advantages over other propellant systems. Liquid hydrazine, in the presence of a suitable catalyst, decomposes to form hydrogen, nitrogen, and ammonia (the amount of ammonia produced is a function of temperature and decomposition chamber residence time). Hydrazine was chosen as the propellant to be modeled, while, bearing in mind, other mono-propellant and bi-propellant combinations could be added to a future simulation program.

The system simulation must be detailed enough to insure that reasonably accurate operating characteristics can be predicted. This

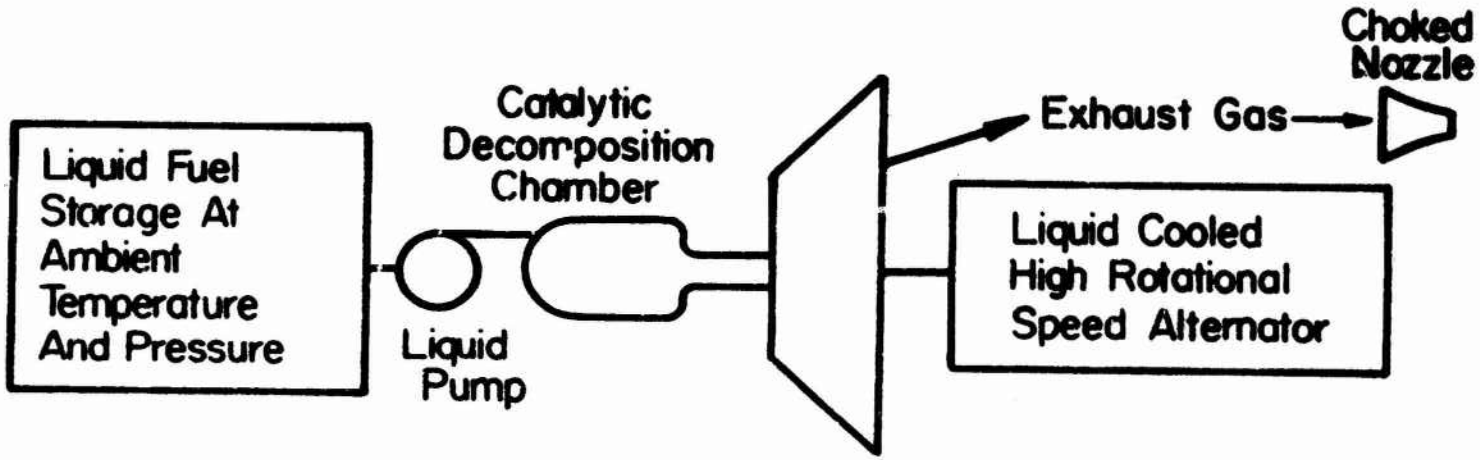


Figure 1. Storable Propellant Turboalternator

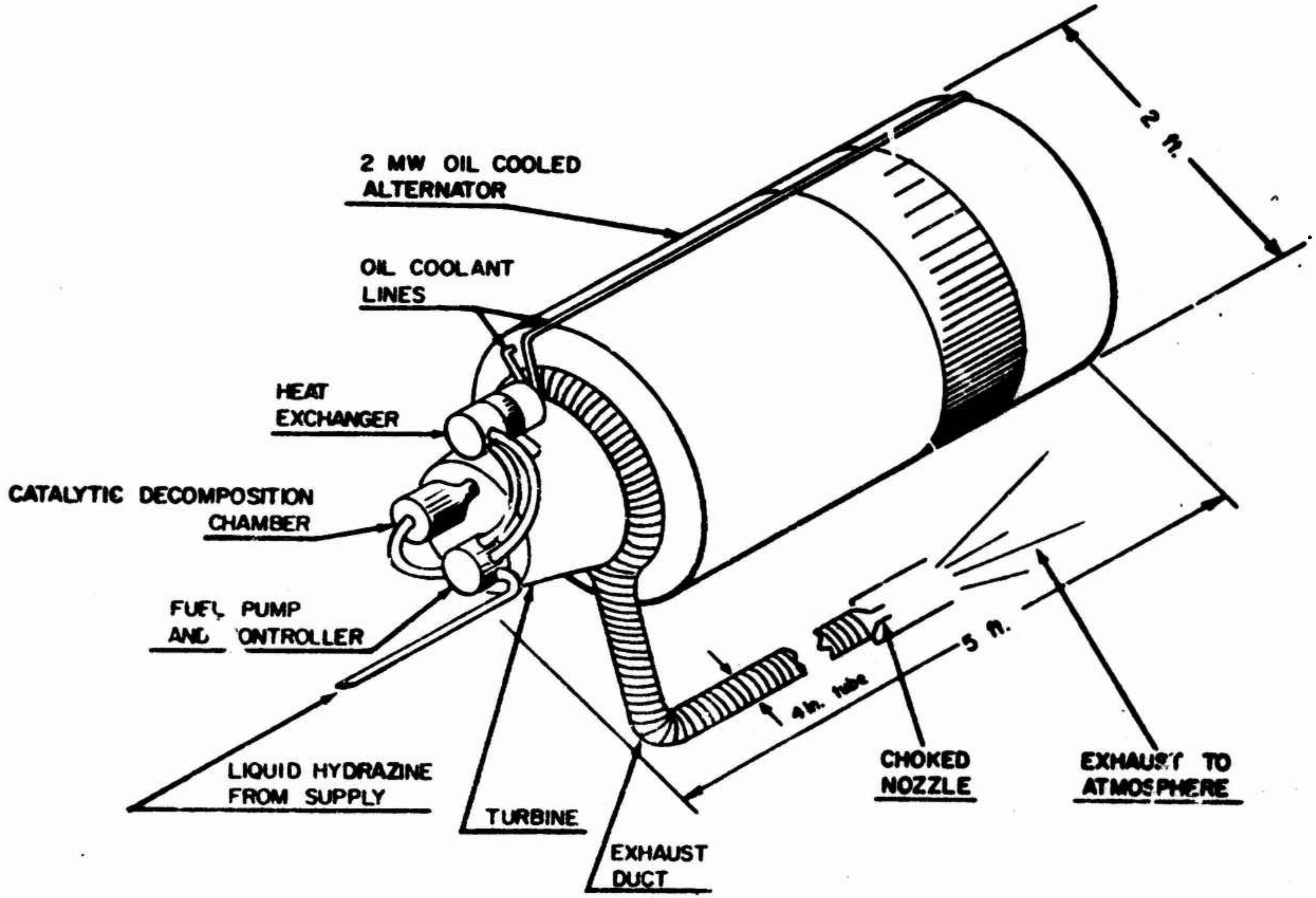


Figure 2 Turboalternator Power System

necessitates use of accurate propellant properties and detailed analysis of the decomposition chamber and gas turbine. The proposed program began at a simple stage with greatly simplified equations with many limiting assumptions and proceeded in a stepwise fashion to a gradually more complex system of equations with fewer limiting assumptions. Throughout this program, an operating time of approximately two hours was assumed reasonable. For this operating time a propellant storage capacity of approximately 14.75 m^3 is required. Two hours is also a safe upper limit in light of present state-of-the art technology of hydrazine decomposition chambers and small, high-speed gas turbines.

2. GENERALIZED SYSTEM SIMULATION PROGRAM

2.1 Turbo-Alternator System Simulation

A system is a collection of related components, and in the turbo-alternator system the components considered were the decomposition chamber, the turbine stages, and the exhaust system. The term "system simulation" may be defined as observing a synthetic system that closely imitates the performance of a real system. As a system simulation, this program predicts the steady-state operating quantities within the system (pressures, temperatures, energy- and fluid-flow rates) at the condition where all energy and material balances, all equations of state of working substances, and all performance characteristics of individual components and controls are satisfied. In the case of the turbo-alternator, no real system yet exists. The equations used in the simulation are all either fundamental equations developed for any similar turbine power system or empirical equations fit to data determined for similar system components (i.e., decomposition chamber). The equations are nearly all non-linear in nature, and, as a result, some special simultaneous method of solution was required. The method chosen was "Newton-Raphson" and a particular generalized system simulation program was used. See Ref. [23].*

2.2 Newton-Raphson Technique for more than One Equation

The Newton-Raphson technique is an iterative method for solving n simultaneous non-linear equations for n unknowns. The general steps,

*Numbers in brackets refer to entries in REFERENCES.

the background for which is found in Ref. [24], are:

1. Move all the terms to one side of each equation,

$$y_1(x_1,x_2,\ldots,x_n) = 0$$

$$y_n(x_1,x_2,\ldots,x_n) = 0$$

2. Assume trial values of the unknowns x_{1t}, x_{2t}, ..., x_{nt} and substitute into the equations. Almost certainly the values of y_1 through y_n will not be zero, so call these values R_1 through R_n.

3. The corrections to be made are found by solving the following set of simultaneous linear equations for the Δx's.

$$R_1 = \frac{\partial y_1}{\partial x_1} \Delta x_1 + \frac{\partial y_1}{\partial x_2} x_2 + \ldots + \frac{\partial y_1}{\partial x_n} \Delta x_n$$

$$R_n = \frac{\partial y_n}{\partial x_1} \Delta x_1 + \frac{\partial y_n}{\partial x_2} \Delta x_2 + \ldots + \frac{\partial y_n}{\partial x_n} \Delta x_n$$

where $\Delta x_1 = (x_{1t} - x_{1,new})$, $\Delta x_2 = (x_{2t} - x_{2,new})$, etc.

4. If the changes in all of the x's are sufficiently small, the computation can be terminated. If not, x_{1t} takes on the value of $x_{1,new}$, x_{2t} becomes $x_{2,new}$, etc., and the process returns to step 2.

In review, the Newton-Raphson method converts the solution of a set of n simultaneous nonlinear equations to an iterative process each iteration of which requires the solution of a set of n simultaneous linear equations.

2.3 Generalized Computer Program

The generalized program used was taken from [2]. It was chosen because of this author's familiarity with both the method and the program

and the program's adaptability to this system. From the standpoint of computer calculations, the operations are as follows:

1. Introduction of trial values of variables,
2. Computation of R's,
3. Calculating the partial derivatives,
4. Solving the simultaneous linear equations,
5. Checking the changes in the x's against some convergence criteria, and
6. If convergence is not satisfied, compute improved values of the x's and return to operation 2.

Operation 1 is the only unique one when moving from one system to another, although to execute operations 2 and 3 a subroutine must be available which can be called to supply the equations unique to the system at hand.

A listing of the generalized program is provided in the appendix. The complete program consists of (1) the main program, (2) the equation subroutine EQNS, (3) the subroutine for extracting the partial derivatives PARDIF, (4) the simultaneous linear equation solver GAUSSY, and (5) the data cards. The main program first reads in the data cards and immediately prints out the values that appear on these data cards. Next the program initializes the iteration counter, because a feature of the program is that if a specified number of iterations are performed, the program terminates even though convergence may not yet be achieved. The program then calls EQNS subroutine to compute the values of the R's. Following this, the main program calls PARDIF which in turn calls EQNS to numerically determine the partial derivatives. The values of the derivatives may be of some interest, particularly for purposes of

analysis if the program fails. Most of the partial derivatives will be zero, especially in large systems, so only the non-zero derivatives are printed out. The partial derivatives and the values of R are transferred to the linear equation solver GAUSSY. The printout now provides the results of this iteration. Finally, the number of iterations and the closing tolerance on the change of all variables is checked, and the program either terminates or returns for another iteration.

3. TURBO-ALTERNATOR SYSTEM AND SYSTEM COMPONENTS

3.1 Decomposition Chamber

The decomposition chamber presents a great challenge in terms of simulation. The processes involved in the catalytic decomposition of hydrazine are complicated and extremely difficult to accurately model. Upon reviewing jet propulsion laboratory abstracts, and the STAR (Scientific and Technical Aerospace Reports) index, ten different papers and reports were found. The most useful among these was a United Aircraft Corporation report [22] which included a computer program for one- and two-dimensional simulations of catalyst chambers. The program itself was not used in this simulation; however, several useful empirical correlations were obtained from the United Aircraft studies. The two equations which are represented graphically in Fig. 3 and 4 are taken directly from typical catalyst chamber data. The equations represent functional relationships between chamber pressure, chamber temperature, mass flow of hydrazine, average catalyst particle size, length and diameter of cylindrical chamber, and fractional dissociation of ammonia gas. These equations are applicable primarily in cases where most of the hydrazine decomposition occurs in the first few millimeters of the reactor; this rapid hydrazine decomposition rate is associated with reactors packed with particles 25 mesh or smaller for approximately 5 mm of bed length. For these cases the correlations work well for axial distances greater than 25 mm and for values of pressure between 69,000 and 690,000 N/m^2 (10 to 1000 psia), a mass flux between 7.05 and 70.5 kg/m^2-sec (1.44 to 14.4 lb_m/ft^2-sec), and equivalent spherical radius between 0.3 and 3 mm. For a reactor packed with small ($\leq$ 25 mesh)

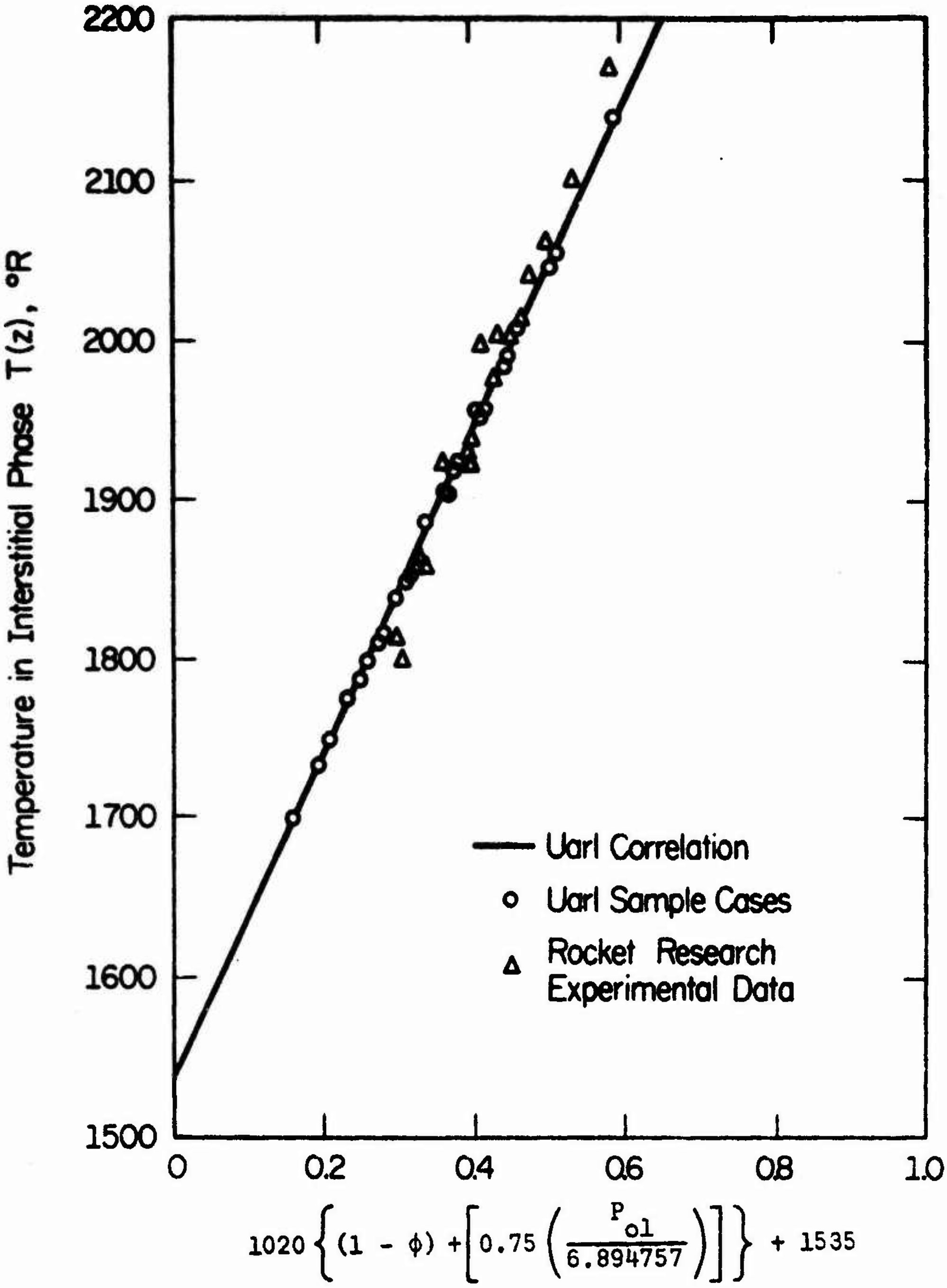
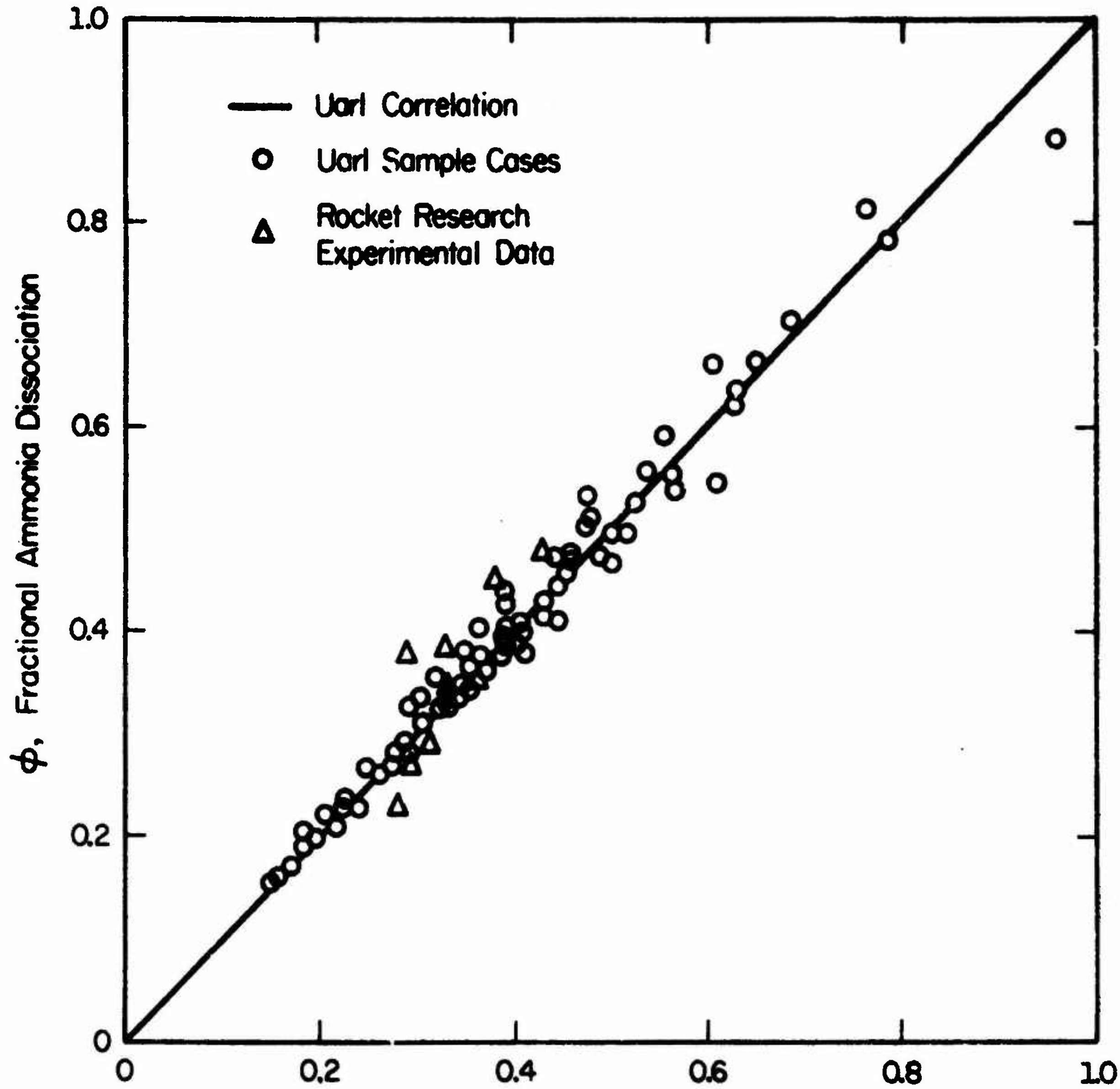


Figure 3 Empirical Correlation for Temperature in a Hydrazine Decomposition Chamber



$$1 - \phi = \left\{0.304 \left[\frac{GO}{Z}\right]^{0.28}\right\} \left\{\left[\left(1.22\ (A)^{0.17} - 0.17\right)\left(\frac{6.8948}{P_{ol}}\right)^{0.22}\right] + 0.17\right\}$$

Figure 4 Empirical Correlation for Fractional A-monia Dissociation in a Hydrazine Decomposition Chamber

particles for the first few millimeters and larger particles thereafter, the particle radius refers to the larger particles.

In order to use these correlations in this program, it was necessary to determine the approximate chamber dimensions for such an application and an estimate of catalyst particle size was also needed. In gas generation applications, the peak performance is achieved with values of fractional dissociation of ammonia of 0.60 to 0.70. By using this criteria and running a simple program with various values of chamber dimensions, a set of reasonable dimensions were determined. Throughout the entire project the following equipment parameters of the cylindrical decomposition chamber were fixed: z = chamber length = 0.203 m, D = chamber diameter = 0.254 m, and A = catalyst particle radius = 3.048 mm.

3.2 Turbine

Since the hardware for this system is presently non-existent, a great deal of work was involved in the turbine modeling. It was not only necessary to develop the simulation equations but also to do a preliminary design so that the model could be considered representative of a typical system. Initial design criteria involved the use of dimensionless flow coefficients and stage loading coefficients to determine the approximate stage configurations. Because of small inlet areas and small blade heights, it was necessary to use partial admission, impulse staging for the first stage. The second and third stages, which were determined necessary to meet the power requirements, seemed best suited to 50 percent reaction staging because of the greater efficiencies attained. The blade velocities were assumed not to exceed 520 m/sec (1700 ft/sec),

this being based upon presently available materials which can withstand the stresses developed at such speeds. Design curves and criteria were taken from Horlock [9], Shepherd [21], Balje [3], and Duisinberre [4]. With the aid of these curves and the equations upon which they were based, physical dimensions, angles, and dimensionless parameters were determined for the design load of 2 mW. Many of these parameters vary, of course, at off-design conditions. All of these off-design parameters were maintained as variables and may be determined for any conditions by the computer program.

The modeling of the turbine consists of three distinct sections: stages 1, 2, and 3. Each section requires five equipment parameters: (1) ALF = angle of gas exit velocity vector from nozzle, (2) BET = angle of relative gas exit velocity vector from rotor, (3) U = blade speed, (4) A = nozzle throat area, and (5) HOB = ratio of blade height to length. All gas properties and velocities are calculated in each stage. The specific heats and the specific heat ratios of the gas are calculated at a mean temperature and pressure in each stage. Loss characteristics based upon blade angles and velocity vector angles were taken from Horlock [9]. More specifically, losses are calculated using the Soderburg loss coefficients for both the stator and the rotor. The total-to-total efficiency of each stage which uses total (stagnation) values of pressure and temperature as references is a function of these loss coefficients, the axial velocity of the gas, the blade speed, and the various inlet and outlet angles. The power produced at each stage is taken from the definition of expansion efficiency where the expansion efficiency is the ratio of actual work to the work developed in an isentropic expansion. The actual work is obtained through the loading

coefficient relationships, while the isentropic work is obtained through simple isentropic pressure ratio relationships.

The total power developed by the turbine is simply the sum of the powers developed by each of the three stages. A total of 62 equations was required to satisfactorily model this turbine. The stage equations are easily broken down into autonomous groups of equations representing a single stage each. It is an easy operation then to modify the turbine design by adding or subtracting stages or changing any of the five equipment parameters associated with a stage.

3.3 Exhaust System

The exhaust system consists simply of an exhaust duct terminating at a converging nozzle. The nozzle is to be choked at all operating conditions. For the purposes of this simulation, the exhaust system was assumed to obey isentropic flow characteristics. The duct cross-sectional area was set at 0.00811 m^2; however, the throat area was allowed to change as a variable. The reasons behind allowing the throat area to change lie in system design; setting the throat area presents a constraint upon the system which must be satisfied, and at this stage final system parameters have not been determined. It was easier to keep throat area as a variable and note how it changed at different load conditions. It was necessary, of course, to set the throat velocity in order to insure choked conditions. In the final system simulation, throat area would likely be an equipment parameter which would not change. This modification will easily be implemented in the present program.

3.4 Variables Used

System or Equipment Variables

A_i = effective rotor exit area of a stage; i = 2, 4, 5 for stages 1, 2, 3, respectively, m^2

C_i = gas velocity at ith stage nozzle exit; i = 1, 3, 5 for stages 1, 2, 3, respectively, m/sec

C_j = gas velocity at jth stage rotor exit; j = 2, 4, 6 for stages 1, 2, 3, respectively, m/sec

C_{AXi} = axial velocity in ith stage; i = 1, 2, 3, m/sec

CP_i = mean specific heat of gas through ith stage; i = 1, 2, 3, J/jg-°K

CP_x = mean specific heat of exhaust gas, J/kg-°K

GO = mass flux through decomposition chamber, kg/sec-m^2

KG_i = mean specific heat ratio of gas through ith stage; i = 1, 2, 3

KG_x = mean specific heat ratio of exhaust gas

$\dot{m}$ = mass flow rate of fuel, kg/sec

MWT = molecular weight of bulk gas, kg/mole

P_i = static pressure at a stage inlet; i = 1, 3, 5 for stages 1, 2, 3, respectively, bars

P_j = static pressure at a stage rotor exit; j = 2, 4, 6 for stages 1, 2, 3, respectively, bars

P_{oi} = total pressure at a stage inlet; i = 1, 3, 5 for stages 1, 2, 3, respectively, bars

P_{o7} = total pressure at third-stage rotor exit, bars

P_D = static pressure in exhaust duct, bars

P_T = static pressure at exhaust nozzle throat, bars

POWi = power output of ith stage, i = 1, 2, 3, mw

Ti = static temperature at a stage inlet; i = 1, 3, 5 for stages 1, 2, 3, respectively, °K

T_j = static temperature at a stage rotor exit; j = 2, 4, 6 for stages 1, 2, 3, respectively, °K

T_{oi} = total temperature at a stage inlet; i = 1, 3, 5 for stages 1, 2, 3, respectively, °K

T_{o7} = total temperature at a third-stage rotor exit, °K

T_D = static temperature in exhaust duct, °K

T_T = static temperature at exhaust nozzle throat, °K

TRBO = turbine power output, mw

V_D = gas velocity in exhaust duct, m/sec

V_T = gas velocity at exhaust nozzle throat, m/sec

X_{H2} = mole fraction of hydrogen

X_{N2} = mole fraction of nitrogen

X_{NH3} = mole fraction of ammonia

α_i = angle of actual gas velocity vector at a stage nozzle exit; i = 3, 5, 7 for stages 1, 2, 3, respectively

β_i = angle of relative gas velocity vector at a stage rotor exit; i = 2, 4, 6 for stages 1, 2, 3, respectively

η_{TTi} = total-to-total efficiency for the ith stage; i = 1, 2, 3

ρ_i = gas density at a stage inlet; i = 1, 3, 5 for stages 1, 2, 3, respectively, lg/m^3

ρ_j = gas density at a stage rotor exit; j = 2, 4, 6 for stages 1, 2, 3, respectively, kg/m^3

ρ_D = gas density in exhaust duct, kg/m^3

ρ_T = gas density at exhaust nozzle throat, kg/m^3

ϕ = fractional dissociation of ammonia

ξ_{Ni} = Soderburg loss coefficient for ith stage stator; $i = 1, 2, 3$

ξ_{Ri} = Soderburg loss coefficient for ith stage rotor; $i = 1, 2, 3$

System of Equipment Parameters

A = average spherical catalyst particle radius, m

A_i = area of ith stage nozzle exit, i = 1, 3, 5 for stages 1, 2, 3, respectively, m^2

A_D = cross section area of exhaust duct, m^2

A_T = cross section area of exhaust nozzle throat, m^2

ALTO = alternator power output, mw

D = diameter of decomposition chamber, m

HOBi = ratio of blade height-to-length in ith stage; i = 1, 2, 3

Ui = rotor blade velocity in ith stage; i = 1, 2, 3, m/sec

Z = length of decomposition chamber, m

α_i = angle of actual gas velocity vector at a stage nozzle exit; i = 2, 4, 6 for stages 1, 2, 3, respectively

β_i = angle of relative gas velocity vector at a stage rotor exit; i = 3, 5, 7 for stages 1, 2, 3, respectively

η_A = alternator efficiency

η_G = gearbox efficiency

4. GAS PROPERTIES

4.1 Decomposition Process

The gas properties and their accurate determination is one of the most important factors in this type of simulation model. An extensive literature search was carried out, and a great deal of useful information about the gas properties was found in Reid [18], McBride [15], Ellenwood [5], Hilsenrath [8], Kubin [11], Obert [16], and Van Wylen [25].

The actual hydrazine decomposition was assumed to be a two-step process:

1. The reaction of hydrazine to ammonia, hydrogen, and nitrogen

$$2N_2H_4 = 2NH_3 + H_2 + N_2 \tag{4.1}$$

2. The dissociation of ammonia into hydrogen and nitrogen

$$2NH_3 = N_2 + 3H_2 \tag{4.2}$$

The preceding equations are the same equations used by United Aircraft Corporation [22] in their analysis of the phenomenon. One important assumption was made at this point: Once the gas leaves the decomposition chamber, no more ammonia dissociates and the bulk gas molecular weight remains constant through the remainder of the system. Actually, this assumption is quite valid and is substantiated by experimental data. From Eqs. (4.1) and (4.2), it is a simple matter to determine all coefficients in terms of the fractional dissociation of ammonia.

$$N_2H_4 = (1 - \phi)\, NH_3 + \frac{1}{2}(1 - \phi)\, N_2 + \frac{1}{2}(1 + 3\phi)\, H_2 \tag{4.3}$$

where ϕ is the fractional dissociation of ammonia. From Eq. (4.3), the

mole fractions of each gas can be expressed as a function of the fractional dissociation of ammonia.

$$X_{NH_3} = (1 - \phi)/(2 + \phi) \tag{4.4}$$

$$X_{N_2} = (1 + \phi)/(4 + 2\phi) \tag{4.5}$$

$$X_{H_2} = (1 + 3\phi)/(4 + 2\phi) \tag{4.6}$$

where X is the mole fraction of each gas in the bulk gas mixture. The molecular weight of the bulk gas is related to the gas mole fractions and the gas molecular weights through Eq. (4.7).

$$MWT = X_{NH_3}*17.032 + X_{N_2}*28.016 + X_{H_2}*2.016 \tag{4.7}$$

4.2 P-ρ-T Relations

The previous equations indicate the assumption of ideal gas behavior. Actually, the gas was assumed to be semi-perfect in behavior; that is, the relationship $P = \rho RT$ was applied, however, certain thermodynamic properties were assumed to be functions of temperature and pressure. The applicability of ideal gas laws was based upon calculations of deviation from ideal behavior using compressibility factors (see APPENDIX A). Although these calculations indicate only deviations of 1 to 3 percent from ideal gas behavior, the deviations for specific heats and specific heat ratios of the gases were much greater.

4.3 Specific Heat Relationships

Zero pressure specific heat data for each of the cases were found in McBride [15], Hilsenrath [8], and Kubin [11]. Third-order polynomial expressions for these specific heat functions of temperature were found in Obert [16] and Van Wylen [25]. These equations were converted to System International units, and specific heat values were generated for different

temperatures and checked with the other data sources mentioned above. The agreement between the calculated and documented values was excellent. The one minor drawback to these equations, however, was their absence of pressure corrections. As is shown graphically in Figs. 5 and 6 (Ellenwood [5]), there is a dependence upon pressure, especially at lower temperatures. The effects of pressure upon specific heat as shown in Figs. 5 and 6 were determined using the Beattie-Bridgeman equations of state. This method of specific heat calculation, although quite accurate and fundamental, is cumbersome. Rather than trying to use Beattie-Bridgeman equations, the polynomial expressions for zero pressure specific heats were "adjusted" to take into account the small variations in the regions of 534°K to 1368°K (500°F to 2000°F) and 0 to 13,800,000 N/m^2 (0 to 2000 psia). The three specific heat equations were combined through the gas mole fractions to give the specific heat of the bulk gas at any temperature and pressure in the above mentioned region.

The ideal relationship between specific heat at constant pressure and specific heat ratio was used to calculate specific heat ratio. (Equations showing these relationships will appear in following chapters.)

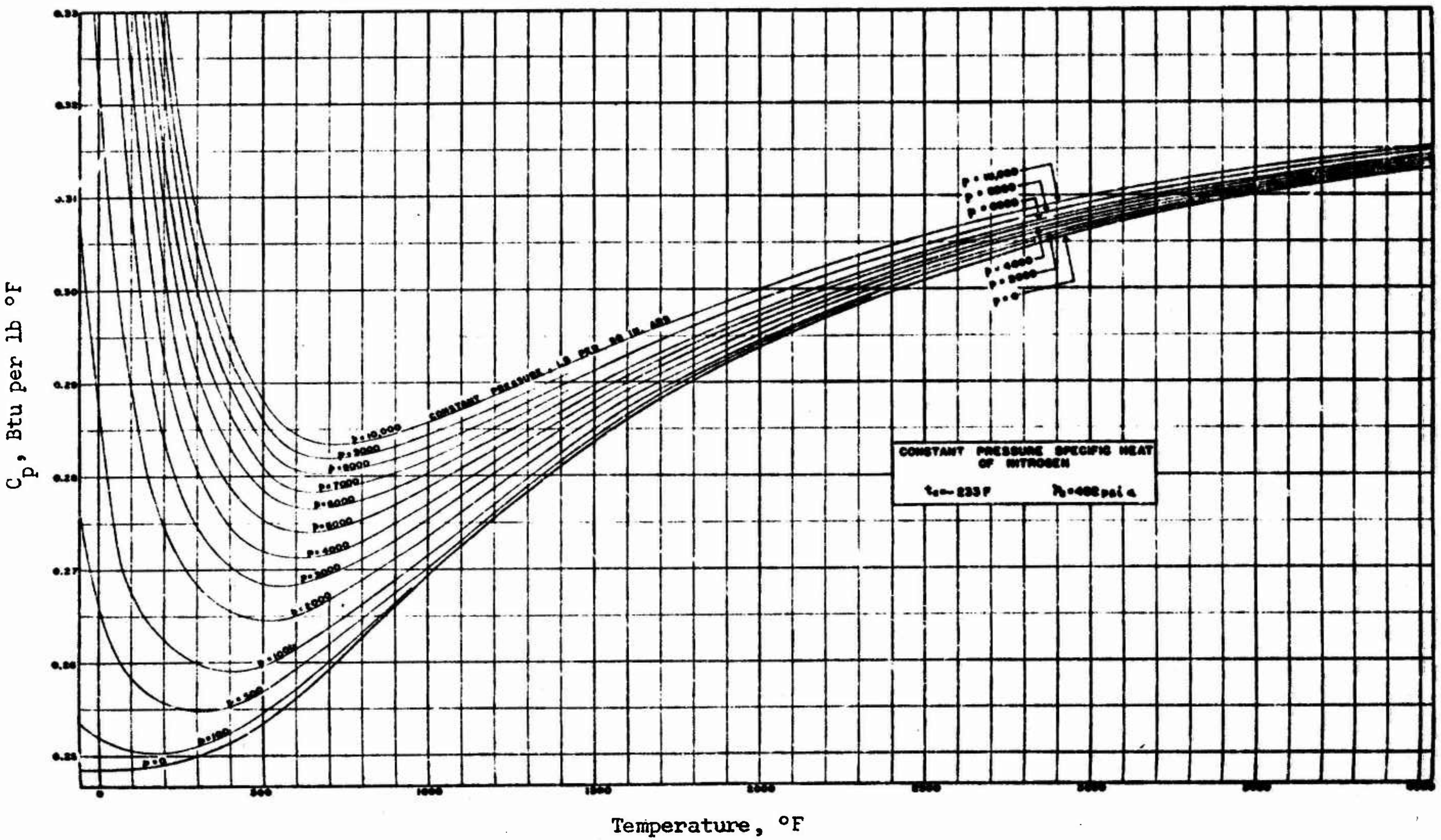


Figure 5 The Effect of Temperature on C_p of Nitrogen at Various Pressures

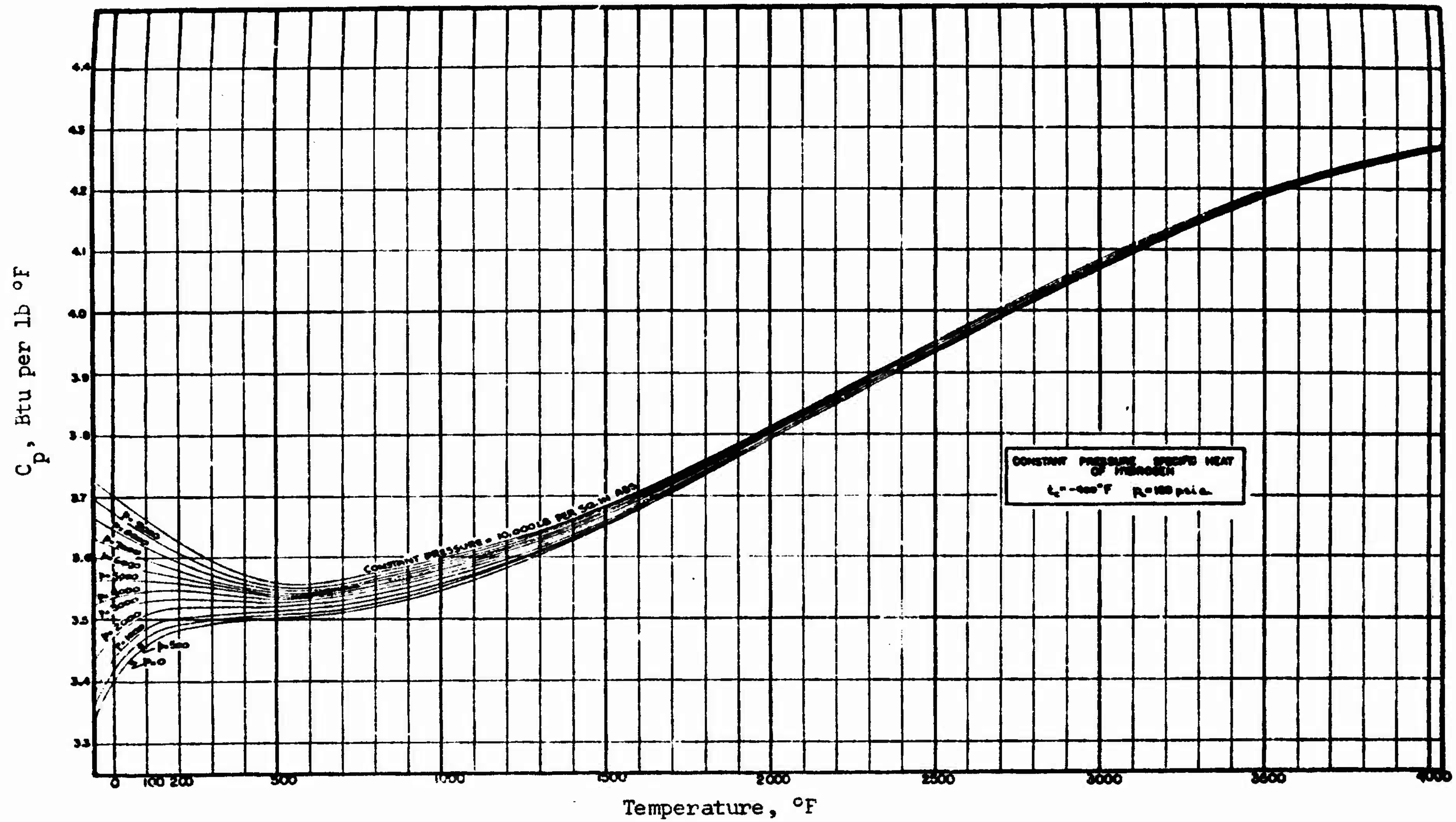


Figure 6 The Effect of Temperature on C_p of Hydrogen at Various Pressures

5. APPLICATION OF FUNDAMENTAL EQUATIONS

The equations used to model the system are described below. The second stage of the turbine was not specifically included because it is the same as the third stage. (The sources and derivations of these equations may be found in APPENDIX A.)

5.1 Alternator Power Equation

$$TRBO = \frac{ALTO}{(\eta_A)(\eta_G)} \tag{5.1}$$

where

$TRBO$ = turbine power output, mw

$ALTO$ = required alternator output, mw

η_A = alternator efficiency

η_G = speed reducer (gearbox) efficiency

5.2 Turbine Power Equation

$$TRBO = POW1 + POW2 + POW3 \tag{5.2}$$

where

$TRBO$ = turbine power output, watts

$POW1$ = power produced in first stage, mw

$POW2$ = power produced in second stage, mw

$POW3$ = power produced in third stage, mw

5.3 Mass Flux Equation

$$GO = \frac{4(\dot{m})}{\pi D^2} \tag{5.3}$$

where

GO = mass flux through decomposition chamber, kg/sec-m^2

$\dot{m}$ = mass flow rate of fuel, kg/sec

D = diameter of cylindrical chamber, m

5.4 Fractional Dissociation of Ammonia Equation

$$\phi = 1 - \left\{0.66\left[\frac{(0.02832)\ GO}{(0.4536)\ (Z)}\right]^{0.28}\right\}\left\{\left[\left(0.55\left(\frac{A}{0.305}\right)^{0.17} - 0.17\right) \cdot \left(\frac{68.94757}{P_{o1}}\right)^{0.22}\right] + 0.17\right\} \quad (5.4)$$

where

ϕ = fractional dissociation of ammonia

Z = length of decomposition chamber, m

A = average spherical catalyst particle radius, m

P_{o1} = total pressure in decomposition chamber, bars

5.5 Decomposition Chamber Temperature Equation

$$T_{o1} = \frac{\left(1020\left\{(1 - \phi) + \left[0.075\left(\frac{P_{o1}}{68.94757}\right)\right]\right\} + 1535\right)}{1.8} \quad (5.5)$$

where

T_{o1} = total temperature in decomposition chamber, °K

5.6 Mole Fraction of Ammonia Equation

$$X_{NH_3} = (1 - \phi)/(2 + \phi) \quad (5.6)$$

where

X_{NH_3} = mole fraction of ammonia

5.7 Mole Fraction of Nitrogen Equation

$$X_{N_2} = (1 + \phi)/4 + 2\phi) \qquad (5.7)$$

where

y_{N_2} = mole fraction of nitrogen

5.8 Mole Fraction of Hydrogen Equation

$$X_{H_2} = (1 + 3\phi)/(4 + 2\phi) \qquad (5.8)$$

where

X_{H_2} = mole fraction of hydrogen

5.9 Molecular Weight Equation

$$MWT = (17.032)\ X_{NH_3} + (28.016)\ X_{N_2} + (2.016)\ X_{H_2} \qquad (5.9)$$

where

MWT = molecular weight of bulk gas, kg/mole

Equations (5.10) through (5.30) represent the set of equations describing the first impulse stage.

5.10 First-Stage Inlet Total Pressure Equation

$$P_{o1} = P_1 + \frac{\rho_1\ C_1^2}{2}\ 10^{-5} \qquad (5.10)$$

where

P_1 = static pressure at first stage nozzle exit, bars

ρ_1 = gas density at first stage nozzle exit, kg/m^3

C_1 = gas velocity at first stage nozzle exit, m/sec

5.11 First-Stage Inlet Total Temperature Equation

$$T_{o1} = T_1 + \frac{C_1^2}{2CP_1} \qquad (5.11)$$

where

T_1 = static temperature at first stage nozzle exit, °K

CP_1 = mean specific heat of gas through first stage, J/kg·°K

5.12 First-Stage Sonic Velocity Equation

$$C_1 = \sqrt{KG_1 \ RT_1} \qquad (5.12)$$

where

KG_1 = mean specific heat ratio through first stage

5.13 First-Stage Inlet Equation of State

$$P_1 = \rho_1 \ RT_1 \ 10^{-5} \qquad (5.13)$$

5.14 First-Stage Inlet Continuity Equation

$$\dot{m} = \rho_1 \ C_1 \ A_1 \qquad (5.14)$$

where

A_1 = area of first stage nozzle, m^2

5.15 Velocity Vector Relationship Equation

$$\tan(\alpha_2) + \tan(\alpha_3) = \tan(\beta_2) + \tan(\beta_3) \qquad (5.15)$$

where

α_2 = angle of actual gas velocity vector at first stage nozzle exit, radians

α_3 = angle of actual gas velocity vector at first stage rotor exit, radians

β_2 = angle of relative gas velocity vector at first stage nozzle exit, radians

β_3 = angle of relative gas velocity vector at first stage rotor exit, radians

5.16 Impulse Stage Angle Equation

$$\beta_2 = \beta_3 \tag{5.16}$$

5.17 First-Stage Specific Work Equation

$$2C_{AX1}\ U1\ [\tan(\beta_3)] = \eta_{TT1}\ CP_1\ T_{o1}\left[1 - \left(\frac{P_{o3}}{P_{o1}}\right)^{[(KG_1-1)/(KG_1)]}\right] \tag{5.17}$$

where

C_{AX1} = axial velocity of gas through first stage, m/sec

$U1$ = first stage blade velocity, m/sec

η_{TT1} = total-to-total efficiency for first stage

P_{o3} = total pressure after first stage, bars

5.18 First-Stage Power Equation

$$POW1 = \dot{m}\ \eta_{TT1}\ CP_1\ T_{o1}\left[1 - \left(\frac{P_{o3}}{P_{o1}}\right)^{[(KG_1-1)/(KG_1)]}\right]10^{-6} \tag{5.18}$$

5.19 First-Stage Exit Total Temperature Equation

$$T_{o3} = T_{o1}\left\{1 - \eta_{TT1}\left[1 - \left(\frac{P_{o3}}{P_{o1}}\right)^{[KG_1-1)/(KG_1)]}\right]\right\} \tag{5.19}$$

where

T_{o3} = total temperature after first stage, $^{\circ}K$

5.20 First-Stage Axial Velocity Equation

$$C_{AX1} = C_1 \, [\cos\, (\alpha_2)] \tag{5.20}$$

5.21 Rotor Loss Coefficient Equation

$$\xi_{R1} = 0.025 \left[1 + \left(\frac{\beta_2 + \beta_3}{1.57}\right)^2\right]\left[1 + \frac{3.2}{HOB1}\right] \tag{5.21}$$

where

ξ_{R1} = Soderburg loss coefficient for first stage rotor

HOB1 = first stage ratio of blade height-to-blade length

5.22 Stator (Nozzle) Loss Coefficient Equation

$$\xi_{N1} = 0.025 \left[1 + \left(\frac{\alpha_1 + \alpha_2}{1.57}\right)^2\right]\left[1 + \frac{3.2}{HOB1}\right] \tag{5.22}$$

where

ξ_{N1} = Soderburg loss coefficient for first stage stator

5.23 First-Stage Total-to-Total Efficiency Equation

$$\eta_{TT1} = \cfrac{1}{1 + \left\{\cfrac{\xi_{N1}\left(\cfrac{C_1}{U1}\right)^2 + \xi_{R1}\left(\cfrac{C_{AX1}}{U1 \cos\, (\beta_3)}\right)^2}{2\left(\cfrac{C_{AX1}}{U1}\right)[\tan\, (\alpha_2) + \tan\, (\alpha_3)]}\right\}} \tag{5.23}$$

5.24 First-Stage Exit Total Pressure Equation

$$P_{o3} = P_2 + \frac{\rho_2 C_2^2}{2} \, 10^{-5} \tag{5.24}$$

where

P_{o3} = static pressure at first stage rotor exit, bars

ρ_2 = density at first stage rotor exit, kg/m^3

C_2 = velocity at first stage rotor exit, m/sec

5.25 First-Stage Exit Total Temperature Equation

$$T_{o3} = T_2 + \frac{C_2^2}{2CP_1} \tag{5.25}$$

where

T_2 = static temperature at first stage rotor exit, °k

5.26 First-Stage Exit Equation of State

$$P_2 = \rho_2 \, RT_2 \, 10^{-5} \tag{5.26}$$

5.27 First-Stage Exit Continuity Equation

$$\dot{m} = \rho_2 \, C_2 \, A_2 \tag{5.27}$$

where

A_2 = calculated effective area of first stage rotor exit, m^2

5.28 First-Stage Rotor Exit Velocity Equation

$$C_2 = \frac{C_{AX1}}{\cos(\alpha_3)} \tag{5.28}$$

5.29 First-Stage Mean Specific Heat Equation

$$CP_1 = \Bigg[\Bigg\{\Bigg[27{,}549.97 + 25.627418\left(\frac{T_1 + T_2}{2}\right) + 9.900599 \times 10^{-3} \cdot \left(\frac{T_1 + T_2}{2}\right)^2 - 6.68603 \times 10^{-6}\left(\frac{T_1 + T_2}{2}\right)^3 + \left(\frac{111}{T_1 + T_2}\right)^2 \cdot \left(\frac{P_1 + P_2}{275.79028}\right)\Bigg] X_{NH_3}\Bigg\} + \Bigg\{\Bigg[28{,}882.15 - 1.570255\left(\frac{T_1 + T_2}{2}\right) + 8.07512 \times 10^{-3}\left(\frac{T_1 + T_2}{2}\right)^2 - 2.87064 \times 10^{-6}\left(\frac{T_1 + T_2}{2}\right)^3 + \left(\frac{111}{T_1 + T_2}\right)^2\left(\frac{P_1 + P_2}{275.79028}\right)\Bigg] X_{N_2}\Bigg\}$$

$$+\left\{\left[29{,}087.17 - 1.914598\left(\frac{T_1 + T_2}{2}\right) + 4.00116 \times 10^{-3}\right.\right.$$

$$\cdot\left(\frac{T_1 + T_2}{2}\right)^2 - 8.69854 \times 0^{-7}\left(\frac{T_1 + T_2}{2}\right)^3 + \left(\frac{111}{T_1 + T_2}\right)^2$$

$$\left.\left.\cdot\left(\frac{P_1 + P_2}{91.93009}\right)\right] X_{H_2}\right\}\Bigg] \div MWT \qquad (5.29)$$

Equation (5.29) is used several times throughout the program to calculate a mean specific heat over a small range of temperature and pressure variation.

5.30 First-Stage Mean Specific Heat Ratio Equation

$$KG_1 = \frac{CP_1}{CP_1 - R} \qquad (5.30)$$

Equation (5.30) is used to calculate a mean value of specific heat ratio based upon the specific heat at constant pressure calculated in Eq. (5.29). Equations (5.31) through (5.50) represent the set of equations used to model the third stage. The second stage is described by a similar set of equations. Both the second and third stages were assumed to be 50 percent reaction stages.

5.31 Third-Stage Inlet Total Pressure Equation

$$P_{o5} = P_5 + \frac{\rho_5 C_5^2}{2} 10^{-5} \qquad (5.31)$$

where

P_{o5} = total pressure after second stage, bars

P_5 = static pressure at third stage nozzle exit, bars

ρ_5 = gas density at third stage nozzle exit, kg/m^3

C_5 = gas velocity at third stage nozzle exit, m/sec

5.32 Third-Stage Inlet Total Temperature Equation

$$T_{o5} = T_5 + \frac{C_5^2}{2CP_3} \qquad (5.32)$$

where

T_{05} = total temperature after second stage, °K

T_5 = static temperature at third stage nozzle exit, °K

CP_3 = mean specific heat in third stage, J/kg-°K

5.33 Third-Stage Inlet Equation of State

$$P_5 = \rho_5 RT_5 10^{-5} \qquad (5.33)$$

5.34 Third-Stage Inlet Continuity Equation

$$\dot{m} = \rho_5 C_5 A_5 \qquad (5.34)$$

where

A_5 = area of third stage nozzle, m^2

5.35 Flow Coefficient Equation

$$\frac{U3}{C_{AX3}} = \tan(\beta_7) - \tan(\beta_6) \qquad (5.35)$$

where

U3 = third stage blade velocity, m/sec

C_{AX3} = axial velocity of gas in third stage, m/sec

β_7 = angle of relative gas velocity vector at third-stage rotor exit, radians

β_6 = angle of relative gas velocity vector at third-stage nozzle exit, radians

5.36 50 Percent Reaction Stage Angle Equation

$$\beta_6 = \alpha_7 \qquad (5.36)$$

where

α_7 = angle of actual gas velocity vector at third stage rotor exit, radians

5.37 Third-Stage Specific Work Equation

$$U3\ C_{AX3}\ [\tan(\alpha_6) + \tan(\alpha_7)] = \eta_{TT3}\ CP_3\ T_{o5} \cdot \left[1 - \left(\frac{P_{o7}}{P_{o5}}\right)^{[(KG_3-1)/(KG_3)]}\right] \tag{5.37}$$

where

α_6 = angle of actual gas velocity vector at third stage nozzle exit, radians

η_{TT3} = total-to-total efficiency for third stage

P_{o7} = total pressure after third stage, bars

KG_3 = mean specific heat ratio in third stage

5.38 Third-Stage Power Equation

$$POW3 = m\ {}_{TT3}\ CP_3\ \eta T_{o5}\left[1 - \left(\frac{P_{o7}}{P_{o5}}\right)^{[(KG_3-1)/(KG_3)]}\right]10^{-6} \tag{5.38}$$

5.39 Third-Stage Exit Total Temperature Equation

$$T_{o7} = T_{o5}\left\{1 - \eta_{TT3}\left[1 - \left(\frac{P_{o7}}{P_{o5}}\right)^{[(KG_3-1)/(KG_3)]}\right]\right\} \tag{5.39}$$

where

T_{o7} = total temperature after third stage, °K

5.40 Third-Stage Axial Velocity Equations

$$C_{AX3} = C_3\ [\cos(\alpha_6)] \tag{5.40}$$

5.41 **Rotor Loss Coefficient Equation**

$$\xi_{R3} = 0.025 \left[1 + \left(\frac{\beta_6 + \beta_7}{1.57}\right)^2\right]\left(1 + \frac{3.2}{HOB3}\right) \tag{5.41}$$

where

ξ_{R3} = Soderburg loss coefficient for third stage rotor

HOB3 = third stage ratio of blade height-to-blade length

5.42 Stator (Nozzle) Loss Coefficient Equation

$$\xi_{N3} = 0.025 \left[1 + \left(\frac{\alpha_5 + \alpha_6}{1.57}\right)^2\right]\left(1 + \frac{3.2}{HOB3}\right) \tag{5.42}$$

where

ξ_{N3} = Soderburg loss coefficient for third stage stator

α_5 = angle of actual gas velocity vector at second stage rotor exit, radians

5.43 Third-Stage Total-to-Total Efficiency Equation

$$\eta_{TT3} = \cfrac{1}{1 + \left\{\cfrac{\xi_{N3}\left(\cfrac{C_5}{U3}\right)^2 + \xi_{R3}\left[\cfrac{C_{AX3}}{U3\ \cos\ (\beta_7)}\right]}{2\left(\cfrac{C_{AX3}}{U3}\right)\left[\tan\ (\alpha_6) + \tan\ (\alpha_7)\right]}\right\}} \tag{5.43}$$

5.44 Third-Stage Exit Total Temperature Equation

$$P_{o7} = P_6 + \frac{\rho_6\ C_6^2}{2}\ 10^{-5} \tag{5.44}$$

where

P_6 = static pressure at third stage rotor exit, bars

ρ_6 = density at third stage rotor exit, kg/m^3

C_6 = velocity at third stage rotor exit, m/sec

5.45 Third-Stage Exit Total Temperature Equation

$$T_{07} = T_6 + \frac{C_6^2}{2CP_3} \qquad (5.45)$$

where

T_6 = static temperature at third stage rotor exit, °K

5.46 Third-Stage Exit Equation of State

$$P_6 = \rho_6 \, RT_6 \, 10^{-5} \qquad (5.46)$$

5.47 Third-Stage Exit Continuity Equation

$$\dot{m} = \rho_6 \, C_6 \, A6 \qquad (5.47)$$

where

A6 = calculated effective area of third stage rotor exit, m^2

5.48 Third-Stage Rotor Exit Velocity Equation

$$C_6 = \frac{C_{AX3}}{\cos(\alpha_7)} \qquad (5.48)$$

5.49 Third-Stage Mean Specific Heat Equation

This equation is identical to Eq. (5.29) except for different mean temperatures and pressures:

$$CP_3 = f(T_5, T_6, P_5, P_6) \qquad (5.49)$$

5.50 Third-Stage Mean Specific Heat Ratio Equation

$$KG_3 = \frac{CP_3}{CP_3 - R} \qquad (5.50)$$

Equations (5.51) through (5.61) represent the equations used to model the exhaust system.

5.51 Exhaust Duct Total Pressure Equation

$$P_{o7} = P_D + \frac{\rho_D V_D^2}{2} 10^{-5} \tag{5.51}$$

where

P_{o7} = total pressure after third stage, bars

P_D = statis pressure in exhaust duct, bars

ρ_D = gas density in exhaust duct, kg/m^3

V_D = gas velocity in exhaust duct, m/sec

5.52 Exhaust Duct Total Temperature Equation

$$T_{o7} = T_D + \frac{V_D^2}{2CP_{EX}} \tag{5.52}$$

where

T_{o7} = total temperature after third stage, °K

T_D = static temperature in exhaust duct, °K

CP_{EX} = mean specific heat of exhaust gas, J/kg-°K

5.53 Exhaust Duct Continuity Equation

$$\dot{m} = \rho_D V_D A_D \tag{5.53}$$

where

A_D = area of exhaust duct cross section, m^2

5.54 Exhaust Duct Equation of State

$$P_D = \rho_D RT_D 10^{-5} \tag{5.54}$$

5.55 Exhaust Nozzle Total Pressure Equation

$$P_{o7} = P_T + \frac{\rho_T V_T^2}{2} 10^{-5} \tag{5.55}$$

where

P_T = static pressure at nozzle throat, bars

ρ_T = gas density at nozzle throat, kg/m^3

V_T = gas velocity at nozzle throat, m/sec

5.56 Exhaust Nozzle Total Temperature Equation

$$T_{o9} = T_T + \frac{V_T^2}{2CP_X} \tag{5.56}$$

where

T_T = static temperature at nozzle throat, °K

5.57 Exhaust Nozzle Continuity Equation

$$\dot{m} = \rho_T \, V_T \, A_T \tag{5.57}$$

where

A_T = area of exhaust nozzle throat, m^2

5.58 Exhaust Nozzle Equation of State

$$P_T = \rho_T \, RT_T \, 10^{-5} \tag{5.58}$$

5.59 Exhaust Nozzle Throat Velocity Equation

$$V_T = \sqrt{KG_X \quad RT_T} \tag{5.59}$$

where

KG_X = mean specific heat ratio of exhaust gas

5.60 Exhaust Gas Mean Specific Heat Equation

Equation (5.60) is the same as Eq. (5.29) and Eq. (5.49) except it is evaluated at a different mean temperature

$$CP_X = f(T_D, T_T, P_D, P_T) \tag{5.60}$$

5.61 Exhaust Gas Mean Specific Heat Ratio

$$KG_X = \frac{CP_X}{CP_X - R} \tag{5.61}$$

6. DISCUSSION OF POSSIBLE FUTURE REFINEMENTS OR ADDITIONS

6.1 Decomposition Chamber

The decomposition chamber representation in the present program is one-dimensional and cannot account for different catalyst bed or inlet port configurations. A future change to the program could be to add the previously mentioned United Aircraft Corporation catalytic chamber two-dimensional simulation [22]. This addition would definitely be a better chamber representation and also would be an excellent first step toward transient system simulation. Ultimately, in order to model a transient system, control devices must be added. The control system models must be complete enough to insure that accurate system response could be determined.

The effect of inlet fuel temperature on system performance was not considered in this program. This effect, although small for small inlet differences, should be considered for the sake of completeness. A complete discussion of the relationships between inlet fuel temperatures and chamber performance appears in Wrobel [26].

6.2 Gas Properties

Although the gases behave nearly ideal in the operating ranges of this program, some error is introduced through the use of ideal gas equations. These small errors could be essentially eliminated through the use of Beattie-Bridgeman or Virial coefficient equations of state. The implementation of these equations could become quite cumbersome, but the increased accuracy of the system model may justify their use. A discussion of the Beattie-Bridgeman equation and the necessary

coefficients may be found in Van Wylen [25], Obert [16], and Ellenwood [5].

6.3 Separate Turbine Simulation

Because of the extensive nature of the turbine simulation, it may become necessary to reduce the actual number of modeling equations. This could be accomplished by completing a separate turbine simulation program and then using the results of such a program to obtain empirical performance curves. These curves could provide accurate simulation equations, but far fewer equations would be required.

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APPENDIX A

The following explanations are supplied for certain of the unique equations found in the simulation program. Many equations which are fundamental (continuity, stagnation pressure, etc.) will not be discussed.

A.1 Equations (5.4) and (5.5)

Equations (5.4) and (5.5) are empirical correlations based upon a significant amount of experimental data. These equations are represented graphically in Figs. 5 and 6 taken from Smith [22].

A.2 Equations (5.7), (5.8), and (5.9)

These gas mole fraction equations were determined according to the decomposition reaction as presented in Eq. (4.2) of this report and in Smith [22].

A.3 Equation (5.13)

Equation (5.13) is essentially a perfect gas correlation. The use of perfect gas laws is substantiated by the following data and calculations. Compressibility factor charts were used to determine the deviation of the gases (under typical conditions) from ideal behavior.

<u>Data</u>

H_2: T_c = 59.7°R and P_c = 188 psia

N_2: T_c = 227.0°R and P_c = 493 psia

NH_3: T_c = 731.4°R and P_c = 1657 psia

Compressibility factor = $Z = Pv/RT$; as $Z \rightarrow 1$ the gas approaches ideal behavior. Then (assuming typical extremes of T = 1500°R and P = 1500 psia) from the generalized chart (Fig. A.1, p. 621 [25]), for H_2, Z = 1.05; for N_2, Z = 1.01; and for NH_3, Z = 0.99. These compressibility factors

show that deviation from 1.0 (ideal gas) is very small and as temperatures become higher and pressures become lower, the chart shows even closer to ideal behavior is observed.

A.4 Equation (5.15)

This equation relates the actual and relative inlet and exit velocity vector angles for the first two impulse stages. This relationship holds for any degree of reaction and was taken from Horlock [9].

A.5 Equation (5.16)

Taken from Horlock [9], this equation results from the definition of an impulse (zero reaction) stage.

A.6 Equation (5.17)

Equation (5.17) is a combination of the definition of stage loading coefficient in Horlock [9] and the efficiency of a turbine. The ideal work is taken from the definition of an isentropic expansion and the actual work is derived from the stage loading coefficient.

A.7 Equations (5.18) and (5.19)

Both Eqs. (5.18) and (5.19) were developed directly from the definitions of expansion efficiency and specific work in Shepherd [21].

A.8 Equation (5.20)

This equation is determined directly from the velocity vector diagram of a typical turbine stage.

A.9 Equations (5.21) and (5.22)

These two equations define the loss coefficients for a turbine stage. These loss coefficients developed by Soderburg were taken from Horlock [9].

A.10 Equation (5.23)

Equation (5.23) is the total-to-total efficiency of a turbine stage in terms of Soderburg loss coefficients, characteristic stage velocities, and angles. This equation was taken from Horlock [9].

A.11 Equation (5.29)

This equation for the specific heat of the gas at any mean temperature and pressure was developed through the use of polynomial expressions for the specific heats of each of the component gases given in Obert [16]. Each of the component gas, molar specific heats is multiplied by the gas mole fraction to obtain the proper "bulk gas" specific heat. There is a correction factor included in each gas polynomial expression to account for pressure effects on specific heat. These correction factors were determined using Figs. 5 and 6 as the basis for nitrogen and hydrogen, respectively. Without any data available, the ammonia factor was assumed to be the same as the nitrogen factor.

A.12 Equation (5.35)

Equation (5.35) is the definition of a flow coefficient for any stage given in Horlock [9]. This equation could be used interchangeably with Eq. (5.15) for a turbine stage in this program. Both provide the necessary geometric constraints on the velocity vector relationships.

A.13 Equation (5.36)

This equation is the geometric relationship which must be satisfied in a 50 percent reaction turbine stage (taken from Horlock [9]).

APPENDIX B

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*****  TURBO-ALTERNATOR SIMULATION PROGRAM WITH A 3 STAGE TURBINE  *****
C
C
C
C     MAIN PROGRAM FOR GENERALIZED SYSTEM SIMULATION
C
C     SUBROUTINES CONSIST OF  (1) EQUATIONS - (2) PARTIAL DERIVATIVES --
C     (3) GAUSSIAN ELIMINATION FOR SIMULTANEOUS SOLUTION OF LINEAR EQS
C
C    GLOSSARY OF TERMS USED IN MAIN PROGRAM
C       ITER = NUMBER OF ITERATIONS
C       ITMAX = MAXIMUM NUMBER OF ITERATIONS TO BE PERMITTED
C       NVAR  =   NUMBER OF UNKNOWNS = NUMBER OF EQUATIONS
C       PD(I,J) = PARTIAL DERIVATIVE OF FUNCTION I WITH RESP TO VARIABLE J
C       R( ) = RESIDUAL OF EQUATION
C       TLRNCE = MAXIMUM FRACTION OF VALUE OF VARIABLES PERMITTED BEFORE
C                ITERATION COMPLETE.  THUS TLRNCE = 0.01 REQUIRES CHANGE OF
C                ALL VARIABLES TO BE LESS THAN 1 PERCENT FOR CONVERGENCE
C       V( ) = VALUE OF THE VARIABLE
C       VCORR( ) = CORRECTION IN THE VARIABLE DURING THIS ITERATION
C       DES( ) = DESIGNATION OF VARIABLE
C
C    INPUT FORMAT
C       FIRST CARD - NVAR IN I3 FIELD RIGHT JUSTIFIED
C       SECOND CARD - TLRNCE IN F10.4 FIELD FOLLOWED BY ITMAX IN 10-SPACES
C       THIRD AND FOLLOWING CARDS ARE THE TRIAL VALUES OF THE VARIABLES
C            IN 8F10.3 FIELDS UNTIL COMPLETE
C     LAST SET OF CARDS CONTAINS VARIABLE DESIGNATIONS IN SEQUENCE IN
C       20A4 FIELDS UNTIL COMPLETE
C
C
C   SYSTEM OR EQUIPMENT PARAMETERS
C
C
C       A=AVERAGE SPHERICAL CATALYST PARTICLE RADIUS (METERS)
C       A1=AREA OF 1ST STAGE NOZZLE EXIT (SQ.M)
C       A3=AREA OF 2ND STAGE NOZZLE EXIT (SQ.M)
C       A5=AREA OF 3RD STAGE NOZZLE EXIT (SQ.M)
C       ADUCT=CROSS SECTIONAL AREA OF EXHAUST DUCT (SQ.M)
C       ALF2=ANGLE OF ACTUAL GAS VELOCITY VECTOR AT THE 1ST STAGE NOZZLE
C       EXIT (RADIANS)
C       ALF4=ANGLE OF ACTUAL GAS VELOCITY VECTOR AT THE 2ND STAGE NOZZLE
C       EXIT (RADIANS)
C       ALF6=ANGLE OF ACTUAL GAS VELOCITY VECTOR AT THE 3RD STAGE NOZZLE
C       EXIT (RADIANS)
C       ALTE=ALTERNATOR EFFICIENCY
C       ALTO=ALTERNATOR POWER OUTPUT (MW)
C       AT=CROSS SECTIONAL AREA OF EXHAUST NOZZLE THROAT (SQ.M)
C       BET3=ANGLE OF RELATIVE GAS VELOCITY VECTOR AT THE 1ST STAGE ROTOR
C       EXIT (RADIANS)
C       BET5=ANGLE OF RELATIVE GAS VELOCITY VECTOR AT THE 2ND STAGE ROTOR
C       EXIT (RADIANS)
C       BET7=ANGLE OF RELATIVE GAS VELOCITY VECTOR AT THE 3RD STAGE ROTOR
C       EXIT (RADIANS)
C       D=DIAMETER OF DECOMPOSITION CHAMBER (M)
C       GRBE=GEARBOX EFFICIENCY
C       HOB1=RATIO OF BLADE HEIGHT TO LENGTH IN 1ST STAGE
C       HOB2=RATIO OF BLADE HEIGHT TO LENGTH IN 2ND STAGE
C       HOB3=RATIO OF BLADE HEIGHT TO LENGTH IN 3RD STAGE
C       U1=ROTOR BLADE VELOCITY IN 1ST STAGE (M/SEC)
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C      U2=ROTOR BLADE VELOCITY IN 2ND STAGE (M/SEC)
C      U3=ROTOR BLADE VELOCITY IN 3RD STAGE (M/SEC)
C      Z=LENGTH OF DECOMPOSITION CHAMBER (M)
C
C  DECOMPOSITION CHAMBER VARIABLES
C
C
C      V( 1)=TURBINE OUTPUT (MW)(BRITISH UNITS=HORSEPOWER)
C      V( 2)=MASS FLOW RATE OF FUEL (KG/SEC)(BRITISH UNITS=LBM/SEC)
C      V( 3)=MASS FLUX THROUGH DECOMPOSITION CHAMBER (KG/SEC-SQ.M)
C           (BRITISH UNITS=LBM/SEC-SQ.FT)
C      V( 4)=FRACTION OF AMMONIA DISSOCIATED
C      V( 5)=MOLE FRACTION OF NH3 GAS
C      V( 6)=MOLE FRACTION OF N2  GAS
C      V( 7)=MOLE FRACTION OF H2  GAS
C      V( 8)=MOECULAR WEIGHT OF GAS (KG/MOLE)(BRITISH UNITS=LBM/MOLE)
C
C
C  TURBINE VARIABLES
C
C
C    FIRST STAGE
C
C      V( 9)=STATIC PRESSURE AT 1ST STAGE INLET (BARS)
C      V(10)=TOTAL PRESSURE AT 1ST STAGE INLET(BARS)
C           (BRITISH UNITS=PSIA)
C           (BRITISH UNITS=PSIA)
C      V(11)=STATIC TEMPERATURE AT 1ST STAGE INLET(DEG K)
C           (BRITISH UNITS=DEG R)
C      V(12)=TOTAL TEMPERATURE AT 1ST STAGE INLET (DEG K)
C           (BRITISH UNITS=DEG R)
C      V(13)=GAS DENSITY AT 1ST STAGE INLET (KG/CU.M)
C           (BRITISH UNITS=LBM/CU.FT)
C      V(14)=GAS VELOCITY AT 1ST STAGE NOZZLE EXIT (M/SEC)
C           (BRITISH UNITS=FT/SEC)
C      V(15)=MEAN SPECIFIC HEAT OF GAS THROUGH 1ST STAGE(JOULES/KG-DEG K)
C           (BRITISH UNITS=BTU/LBM-DEG R)
C      V(16)=MEAN SPECIFIC HEAT RATIO THROUGH 1ST STAGE
C      V(17)=SODERBURG LOSS COEFFICIENT FOR 1ST STAGE ROTOR
C      V(18)=SODERBURG LOSS COEFFICIENT FOR 1ST STAGE STATOR
C      V(19)=TOTAL TO TOTAL EFFICIENCY FOR 1ST STAGE
C      V(20)=AXIAL VELOCITY OF GAS IN 1ST STAGE (M/SEC)
C           (BRITISH UNITS=FT/SEC)
C      V(21)=STATIC PRESSURE AT 1ST STAGE ROTOR EXIT (BARS)
C           (BRITISH UNITS=PSIA)
C      V(22)=TOTAL PRESSURE AFTER 1ST STAGE(BARS)(BRITISH UNITS=PSIA)
C      V(23)=STATIC TEMP. AT 1ST STAGE ROTOR EXIT (DEG K)
C           (BRITISH UNITS=DEG K)
C      V(24)=TOTAL TEMP. AFTER 1ST STAGE (DEG K) (BRITISH UNITS=DEG R)
C      V(25)=GAS DENSITY AT 1ST STAGE ROTOR EXIT KG/CU.M)
C           (BRITISH UNITS=LBM/CU.FT)
C      V(26)=GAS VELOCITY AT 1ST STAGE ROTOR EXIT (M/SEC)
C           (BRITISH UNITS=FT/SEC)
C      V(27)=ANGLE OF RELATIVE GAS VELOCITY VECTOR AT 1ST STAGE NOZZLE
C      EXIT (RADIANS) (BRITISH UNITS=DEGREES)
C      V(28)=ANGLE OF ACTUAL GAS VELOCITY VECTOR AT 1ST STAGE ROTOR EXIT
C           (RADIANS) (BRITISH UNITS=DEGREES)
C      V(29)=EFFECTIVE ROTOR EXIT AREA OF 1ST STAGE (SQ.M)
C           (BRITISH UNITS=SQ.FT)
C      V(30)=POWER OUTPUT OF 1ST STAGE (MW)(BRITISH UNITS=HORSEPOWER)
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C     V(31)=STATIC PRESSURE AT 2ND STAGE INLET (BARS)
C
C    SECOND STAGE
C
C          (BRITISH UNITS=PSIA)
C     V(32)=STATIC TEMPERATURE AT 2ND STAGE INLET(DEG K)
C          (BRITISH UNITS=DEG R)
C     V(33)=GAS DENSITY AT 2ND STAGE INLET (KG/CU.M)
C          (BRITISH UNITS=LBM/CU.FT)
C     V(34)=GAS VELOCITY AT 2ND STAGE NOZZLE EXIT (M/SEC)
C          (BRITISH UNITS=FT/SEC)
C     V(35)=MEAN SPECIFIC HEAT OF GAS THROUGH 2ND STAGE(JOULES/KG-DEG K)
C          (BRITISH UNITS=BTU/LBM-DEG R)
C     V(36)=MEAN SPECIFIC HEAT RATIO THROUGH 2ND STAGE
C     V(37)=SODERBURG LOSS COEFFICIENT FOR 2ND STAGE ROTOR
C     V(38)=SODERBURG LOSS COEFFICIENT FOR 2ND STAGE STATOR
C     V(39)=TOTAL TO TOTAL EFFICIENCY FOR 2ND STAGE
C     V(40)=AXIAL VELOCITY OF GAS IN 2ND STAGE (M/SEC)
C         (BRITISH UNITS=FT/SEC)
C     V(41)=STATIC PRESSURE AT 2ND STAGE ROTOR EXIT (BARS)
C          (BRITISH UNITS=PSIA)
C     V(42)=TOTAL PRESSURE AFTER 2ND STAGE (BARS)(BRITISH UNITS=PSIA)
C     V(43)=STATIC TEMP. AT 2ND STAGE ROTOR EXIT (DEG K)
C          (BRITISH UNITS=DEG R)
C     V(44)=TOTAL TEMP. AFTER 2ND STAGE (DEG K) (BRITISH UNITS=DEG R)
C     V(45)=GAS DENSITY AT 2ND STAGE ROTOR EXIT KG/CU.M)
C          (BRITISH UNITS=LBM/CU.FT)
C     V(46)=GAS VELOCITY AT 2ND STAGE ROTOR EXIT (M/SEC)
C          (BRITISH UNITS=FT/SEC)
C     V(47)=ANGLE OF RELATIVE GAS VELOCITY VECTOR AT 2ND STAGE NOZZLE
C     EXIT (RADIANS) (BRITISH UNITS=DEGREES)
C     V(48)=ANGLE OF ACTUAL GAS VELOCITY VECTOR AT 2ND STAGE ROTOR EXIT
C          (RADIANS) (BRITISH UNITS=DEGREES)
C     V(49)=EFFECTIVE ROTOR EXIT AREA OF 2ND STAGE (SQ.M)
C          (BRITISH UNITS=SQ.FT)
C     V(50)=POWER OUTPUT OF 2ND STAGE (MW)(BRITISH UNITS=HORSEPOWER)
C
C    THIRD STAGE
C
C     V(51)=STATIC PRESSURE AT 3RD STAGE INLET (BARS)
C          (BRITISH UNITS=PSIA)
C     V(52)=STATIC TEMPERATURE AT 3RD STAGE INLET(DEG K)
C          (BRITISH UNITS=DEG R)
C     V(53)=GAS DENSITY AT 3RD STAGE INLET (KG/CU.M)
C          (BRITISH UNITS=LBM/CU.FT)
C     V(54)=GAS VELOCITY AT 3RD STAGE NOZZLE EXIT (M/SEC)
C          (BRITISH UNITS=FT/SEC)
C     V(55)=MEAN SPECIFIC HEAT OF GAS THROUGH 3RD STAGE(JOULES/KG-DEG K)
C          (BRITISH UNITS=BTU/LBM-DEG R)
C     V(56)=MEAN SPECIFIC HEAT RATIO THROUGH 3RD STAGE
C     V(57)=SODERBURG LOSS COEFFICIENT FOR 3RD STAGE ROTOR
C     V(58)=SODERBURG LOSS COEFFICIENT FOR 3RD STAGE STATOR
C     V(59)=TOTAL TO TOTAL EFFICIENCY FOR 3RD STAGE
C     V(60)=AXIAL VELOCITY OF GAS IN 3RD STAGE (M/SEC)
C          (BRITISH UNITS=FT/SEC)
C     V(61)=STATIC PRESSURE AT 3RD STAGE ROTOR EXIT (BARS)
C     V(62)=TOTAL PRESSURE AFTER 3RD STAGE (BARS)(BRITISH UNITS=PSIA)
C          (BRITISH UNITS=PSIA)
C     V(63)=STATIC TEMP. AT 3RD STAGE ROTOR EXIT (DEG K)
C          (BRITISH UNITS=DEG R)
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C     V(64)=TOTAL TEMP. AFTER 3RD STAGE (DEG K) (BRITISH UNITS=DEG R)
C     V(65)=GAS DENSITY AT 3RD STAGE ROTOR EXIT KG/CU.M)
C          (BRITISH UNITS=LBM/CU.FT)
C     V(66)=GAS VELOCITY AT 3RD STAGE ROTOR EXIT (M/SEC)
C          (BRITISH UNITS=FT/SEC)
C     V(67)=ANGLE OF RELATIVE GAS VELOCITY VECTOR AT 3RD STAGE NOZZLE
C     EXIT (RADIANS) (BRITISH UNITS=DEGREES)
C     V(68)=ANGLE OF ACTUAL GAS VELOCITY VECTOR AT 3RD STAGE ROTOR EXIT
C          (RADIANS) (BRITISH UNITS=DEGREES)
C     V(69)=EFFECTIVE ROTOR EXIT AREA OF 3RD STAGE (SQ.M)
C          (BRITISH UNITS=SQ.FT)
C     V(70)=POWER OUTPUT OF 3RD STAGE (MW)(BRITISH UNITS=HORSEPOWER)
C
C
C  EXHAUST SYSTEM VARIABLES
C
C
C     V(71)=STATIC PRESSURE IN EXHAUST DUCT (BARS)
C          (BRITISH UNITS=PSIA)
C     V(72)=STATIC TEMP. IN EXHAUST DUCT (DEG K)(BRITISH UNITS=DEG R)
C     V(73)=GAS DENSITY IN EXHAUST DUCT (KG/CU.M)
C          (BRITISH UNITS=LBM/CU.FT)
C     V(74)=GAS VELOCITY IN EXHAUST DUCT (M/SEC)
C          (BRITISH UNITS=FT/SEC)
C     V(75)=STATIC PRESSURE AT EXHAUST NOZZLE THROAT (BARS)
C          (BRITISH UNITS=PSIA)
C     V(76)=STATIC TEMP. AT EXHAUST NOZZLE THROAT(DEG K)
C          (BRITISH UNITS=DEG R)
C     V(77)=GAS DENSITY AT EXHAUST NOZZLE THROAT (KG/CU.M)
C          (BRITISH UNITS=LBM/CU.FT)
C     V(78)=GAS VELOCITY AT EXHAUST NOZZLE THROAT (M/SEC)
C          (BRITISH UNITS=FT/SEC)
C     V(79)=MEAN SPECIFIC HEAT OF EXHAUST GAS (JOULES/KG-DEG K)
C          (BRITISH UNITS=BTU/LBM-DEG R)
C     V(80)=MEAN SPECIFIC HEAT RATIO OF EXHAUST GAS
C     V(81)=EFFECTIVE EXHAUST NOZZLE THROAT AREA (SQ.M)
C          (BRITISH UNITS=SQ.FT)
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```
C
      DIMENSION V(81),R(81),PD(81,81),VCORR(81),DES(81),O(81)
      COMMON A,Z,D,ALF2,ALF4,ALF6,ALF8,ALF10,BET3,BET5,BET7,BET9,BET11
      COMMON HOB1,HOB2,HOB3,HOB4,HOB5,U1,U2,U3,U4,U5,A1,A3,A5,A7,A9
      COMMON AT,ADUCT,ALF1
      COMMON ALTO,GRBE,ALTE
C
C   READING THE DATA CARDS
C
      READ(5,10) NVAR
   10 FORMAT(I3)
      READ(5,11) TLRNCE, ITMAX
   11 FORMAT(F10.4, I10)
      READ(5,12) (V(I), I = 1,NVAR)
   12 FORMAT(8F10.3)
      READ (5,13)  (DES(I), I = 1, NVAR)
   13 FORMAT (20A4)
      DO 1000 LM=1,5
      ALTO=2.0-.4*(LM-1)
      ALTE=.9
      GRBE=.95
      D=.254
      Z=.203
      A=.003048
      ALF1=0.
      ALF2=1.29
      BET3=1.03
      U1=516.
      A1=.000229
      HOB1=1.25
      ALF4=1.2277
      BET5=1.2277
      U2=516.
      A3=.000567
      HOB2=1.25
      ALF6=1.2277
      BET7=1.2277
      A5=.00102
      U3=516.
      HOB3=1.25
      ADUCT=.00811
C
C   WRITING OUT THE INPUT DATA
C
      WRITE(6,20) NVAR
   20 FORMAT(1H1,///,' NUMBER OF VARIABLES = ', I4)
      WRITE(6,21) TLRNCE
   21 FORMAT(' MAXIMUM FRACTION CHANGE FOR CONVERGENCE =', F10.4, //)
      WRITE(6,22)
   22 FORMAT('OVARIABLE NUMBER AND ITS TRIAL VALUE')
      WRITE (6,23)  (J, DES(J), V(J), J = 1, NVAR)
   23 FORMAT (' V(', I3, ') = ', A4, ' = ', F15.5)
C
```

```
      C   INITIALIZING THE ITERATION COUNTER
            ITER = 1
      C   CALLING SUBROUTINES TO CALCULATE VALUES OF RESIDUALS, PARTIAL
      C        DERIVATIVES AND CHANGES IN VALUES OF VARIABLES
      C
         30 CALL EQNS(NVAR, V, R)
      C     WRITE (6,33)
      C  33 FORMAT('0EQUATION NUMBER       RESIDUAL')
      C     WRITE (6,35)  (I , R(I),  I = 1,NVAR)
      C  35 FORMAT (I10, F20.5)
            CALL PARDIF(NVAR, V, R, PD)
      C
      C    PRINTING OUT NON-ZERO VALUES OF PARTIAL DERIVATIVES
      C
            DO 54  I = 1, NVAR
            DO 53  J = 1, NVAR
            ZT= ABS(PD(I,J))
      C     REMOVE THE C FROM THE NEXT THREE CARDS IF PRINTOUT DESIRED
      C     IF(ZT- 0.00000001) 53, 53, 51
      C  51 WRITE(6,52) I, J, PD(I,J)
      C  52 FORMAT(' PD(',I2,',',I2,') =', F20.10)
         53 CONTINUE
         54 CONTINUE
            CALL GAUSSY(PD, R, VCORR, NVAR)
      C     CORRECTING THE VALUES OF THE VARIABLES
            DO 44  L = 1,NVAR
         44 V(L) = V(L) - VCORR(L)
      C
            Q( 1)=V( 1)/745.7E-06
            Q( 2)=V( 2)*2.20462
            Q( 3)=V( 3)*2.20462*.092903
            Q( 4)=V( 4)
            Q( 5)=V( 5)
            Q( 6)=V( 6)
            Q( 7)=V( 7)
            Q( 8)=V( 8)
            Q( 9)=V( 9)/6894.757E-05
            Q(10)=V(10)/6894.757E-05
            Q(11)=V(11)*1.8
            Q(12)=V(12)*1.8
            Q(13)=V(13)/16.02
            Q(14)=V(14)/.3048
            Q(15)=V(15)/4184.
            Q(16)=V(16)
            Q(17)=V(17)
            Q(18)=V(18)
            Q(19)=V(19)
            Q(20)=V(20)/.3048
            Q(21)=V(21)/6894.757E-05
            Q(22)=V(22)/6894.757E-05
            Q(23)=V(23)*1.8
            Q(24)=V(24)*1.8
            Q(25)=V(25)/16.02
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```
      O(26)=V(26)/.3048
      O(27)=V(27)*57.3
      O(28)=V(28)*57.3
      O(29)=V(29)/(.3048**2)
      O(30)=V(30)/745.7E-06
      O(31)=V(31)/6894.757E-05
      O(32)=V(32)*1.8
      O(33)=V(33)/16.02
      O(34)=V(34)/.3048
      O(35)=V(35)/4184.
      O(36)=V(36)
      O(37)=V(37)
      O(38)=V(38)
      O(39)=V(39)
      O(40)=V(40)/.3048
      O(41)=V(41)/6894.757E-05
      O(42)=V(42)/6894.757E-05
      O(43)=V(43)*1.8
      O(44)=V(44)*1.8
      O(45)=V(45)/16.02
      O(46)=V(46)/.3048
      O(47)=V(47)*57.3
      O(48)=V(48)*57.3
      O(49)=V(49)/(.3048**2)
      O(50)=V(50)/745.7E-06
      O(52)=V(52)*1.8
      O(51)=V(51)/6894.757E-05
      O(53)=V(53)/16.02
      O(54)=V(54)/.3048
      O(55)=V(55)/4184.
      O(56)=V(56)
      O(57)=V(57)
      O(58)=V(58)
      O(59)=V(59)
      O(60)=V(60)/.3048
      O(61)=V(61)/6894.757E-05
      O(62)=V(62)/6894.757E-05
      O(63)=V(63)*1.8
      O(64)=V(64)*1.8
      O(65)=V(65)/16.02
      O(66)=V(66)/.3048
      O(67)=V(67)*57.3
      O(68)=V(68)*57.3
      O(69)=V(69)/(.3048**2)
      O(70)=V(70)/745.7E-06
      O(71)=V(71)/6894.757E-05
      O(72)=V(72)*1.8
      O(73)=V(73)/16.02
      O(74)=V(74)/.3048
      O(75)=V(75)/6894.757E-05
      O(76)=V(76)*1.8
      O(77)=V(77)/16.02
      O(78)=V(78)/.3048
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      O(79)=V(79)/4184.
      O(80)=V(80)
      O(81)=V(81)/(.3048**2)
C
C   WRITING OUT RESULTS OF THIS ITERATION
C
C     TO PRINT OUT EVERY ITERATION REMOVE COMMENT NOTATION FROM
C     FOLLOWING CARDS
C
C   WRITING OUT RESULTS OF THIS ITERATION
C
C     WRITE (6,32) ITER
C  32 FORMAT('ORESULTS AFTER', I4, '  ITERATIONS')
C     WRITE(6,34)
C  34 FORMAT('0',4X,'VARIABLE',16X,'VALUE',9X,'CHANGE FROM PREVIOUS')
C     WRITE (6,36)  (I, DES(I), V(I), VCORR(I), I = 1,NVAR)
C  36 FORMAT (' V(', I2, ') = ', A4,' = ', 2F21.5)
C
C   TERMINATING IF MAXIMUM NUMBER OF ITERATIONS REACHED OR OTHERWISE
C        INCREMENTING THE ITERATION COUNTER
      IF(ITER - ITMAX) 38, 99, 99
   38 ITER = ITER + 1
C
C   CHECK TO SEE IF CHANGE OF VARIABLE IS LESS THAN SPECIFIED TOLERANCE
C
      K = 1
   40 VAL = ABS(VCORR(K)) - ABS(TLRNCE*V(K))
      IF(VAL) 41, 30, 30
   41 IF(K - NVAR) 42, 99, 99
   42 K = K + 1
      GO TO 40
   99 WRITE(6,122)
  122 FORMAT(1H1)
      WRITE(6,111)
  111 FORMAT('OVARIABLE NUMBER AND ITS FINAL VALUE'/)
      WRITE(6,1973) ALTO
 1973 FORMAT(' THESE VALUES ARE FOR AN ALTERNATOR OUTPUT OF ',F4.2,' MW'
     1/)
      WRITE(6,112)
  112 FORMAT('0',4X,'VARIABLE',12X,'VALUE(SI)',21X,'VALUE(BRITISH)')
      WRITE(6,113)(NM,DES(NM),V(NM),O(NM),NM=1,15)
  113 FORMAT(' V(',I2, ') = ', A4,' = ',F14.5,' MW            ',F14.5,' H
     1P',/,
     2' V(',I2,') = ',A4,' = ',F14.5,' KG/SEC ',6X,F14.5,' LBM/SEC ',/,
     3' V(',I2,') = ',A4,' = ',F14.5,' KG/SEC-SQ.M',2X,F14.5,' LBM/SEC-S
     40.FT',/,
     5' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
     6' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
     7' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
     8' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
     9' V(',I2,') = ',A4,' = ',F14.5,' KG/MOLE',6X,F14.5,' LBM/MOLE',//,
     1' V(',I2,') = ',A4,' = ',F14.5,' BARS   ',6X,F14.5,' PSIA     ',/,
     2' V(',I2,') = ',A4,' = ',F14.5,' BARS   ',6X,F14.5,' PSIA     ',/,
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         3' V(',I2,') = ',A4,' = ',F14.5,' DEG K   ',6X,F14.5,' DEG R    ',/,
         4' V(',I2,') = ',A4,' = ',F14.5,' DEG K   ',6X,F14.5,' DEG R    ',/,
         5' V(',I2,') = ',A4,' = ',F14.5,' KG/CU.M',6X,F14.5,' LBM/CU.FT',/,
         6' V(',I2,') = ',A4,' = ',F14.5,' M/SEC   ',6X,F14.5,' FT/SEC   ',/,
         7' V(',I2,') = ',A4,' = ',F14.5,' J/KG-DEG K',3X,F14.5,' BTU/LBM-DE
         8G R')
0156       WRITE(6,114)(NM,DES(NM),V(NM),O(NM),NM=16,30)
0157   114 FORMAT(' V(',I2, ') = ', A4,' = ',F14.5,'                ',F14.5,/,
         1' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
         2' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
         3' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
         4' V(',I2,') = ',A4,' = ',F14.5,' M/SEC   ',6X,F14.5,' FT/SEC   ',/,
         5' V(',I2,') = ',A4,' = ',F14.5,' BARS    ',6X,F14.5,' PSIA     ',/,
         6' V(',I2,') = ',A4,' = ',F14.5,' BARS    ',6X,F14.5,' PSIA     ',/,
         7' V(',I2,') = ',A4,' = ',F14.5,' DEG K   ',6X,F14.5,' DEG R    ',/,
         8' V(',I2,') = ',A4,' = ',F14.5,' DEG K   ',6X,F14.5,' DEG R    ',/,
         9' V(',I2,') = ',A4,' = ',F14.5,' KG/CU.M',6X,F14.5,' LBM/CU.FT',/,
         1' V(',I2,') = ',A4,' = ',F14.5,' M/SEC   ',6X,F14.5,' FT/SEC   ',/,
         2' V(',I2,') = ',A4,' = ',F14.5,' RADIANS',6X,F14.5,' DEGREES ',/,
         3' V(',I2,') = ',A4,' = ',F14.5,' RADIANS',6X,F14.5,' DEGREES ',/,
         4' V(',I2,') = ',A4,' = ',F14.5,' SQ.M    ',6X,F14.5,' SQ.FT    ',/,
         5' V(',I2,') = ',A4,' = ',F14.5,' MW      ',6X,F14.5,' HP '     ,/)
0158       WRITE(6,115)(NM,DES(NM),V(NM),O(NM),NM=31,40)
0159   115 FORMAT(' V(',I2, ') = ', A4,' = ',F14.5,' BARS           ',F14.5,' P
         1SIA',/,
         2' V(',I2,') = ',A4,' = ',F14.5,' DEG K   ',6X,F14.5,' DEG R    ',/,
         3' V(',I2,') = ',A4,' = ',F14.5,' KG/CU.M',6X,F14.5,' LBM/CU.FT',/,
         4' V(',I2,') = ',A4,' = ',F14.5,' M/SEC   ',6X,F14.5,' FT/SEC   ',/,
         5' V(',I2,') = ',A4,' = ',F14.5,' J/KG-DEG K',3X,F14.5,' BTU/LBM-DE
         6G R',/,
         7' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
         8' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
         9' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
         1' V(',I2,') = ',A4,' = ',F14.5,'         ',6X,F14.5,'          ',/,
         2' V(',I2,') = ',A4,' = ',F14.5,' M/SEC   ',6X,F14.5,' FT/SEC   ' )
0160       WRITE(6,116)(NM,DES(NM),V(NM),O(NM),NM=41,50)
0161   116 FORMAT(' V(',I2, ') = ', A4,' = ',F14.5,' BARS           ',F14.5,' P
         1SIA',/,
         2' V(',I2,') = ',A4,' = ',F14.5,' BARS    ',6X,F14.5,' PSIA     ',/,
         4' V(',I2,') = ',A4,' = ',F14.5,' DEG K   ',6X,F14.5,' DEG R    ',/,
         5' V(',I2,') = ',A4,' = ',F14.5,' DEG K   ',6X,F14.5,' DEG R    ',/,
         6' V(',I2,') = ',A4,' = ',F14.5,' KG/CU.M',6X,F14.5,' LBM/CU.FT',/,
         7' V(',I2,') = ',A4,' = ',F14.5,' M/SEC   ',6X,F14.5,' FT/SEC   ',/,
         8' V(',I2,') = ',A4,' = ',F14.5,' RADIANS',6X,F14.5,' DEGREES ',/,
         9' V(',I2,') = ',A4,' = ',F14.5,' RADIANS',6X,F14.5,' DEGREES ',/,
         1' V(',I2,') = ',A4,' = ',F14.5,' SQ.M    ',6X,F14.5,' SQ.FT    ',/,
         2' V(',I2,') = ',A4,' = ',F14.5,' MW      ',6X,F14.5,' HP '     ,/)
0162       WRITE(6,117)(NM,DES(NM),V(NM),O(NM),NM=51,60)
0163   117 FORMAT(' V(',I2, ') = ', A4,' = ',F14.5,' BARS           ',F14.5,' P
         1SIA',/,
         2' V(',I2,') = ',A4,' = ',F14.5,' DEG K   ',6X,F14.5,' DEG R    ',/,
         3' V(',I2,') = ',A4,' = ',F14.5,' KG/CU.M',6X,F14.5,' LBM/CU.FT',/,
         4' V(',I2,') = ',A4,' = ',F14.5,' M/SEC   ',6X,F14.5,' FT/SEC   ',/,
```

```
          5' V(',I2,') = ',A4,' = ',F14.5,' J/KG-DEG K',3X,F14.5,' BTU/LBM-DE
          6G R',/,
          7' V(',I2,') = ',A4,' = ',F14.5,'           ',6X,F14.5,'           ',/,
          8' V(',I2,') = ',A4,' = ',F14.5,'           ',6X,F14.5,'           ',/,
          9' V(',I2,') = ',A4,' = ',F14.5,'           ',6X,F14.5,'           ',/,
          1' V(',I2,') = ',A4,' = ',F14.5,'           ',6X,F14.5,'           ',/,
          2' V(',I2,') = ',A4,' = ',F14.5,' M/SEC     ',6X,F14.5,' FT/SEC     ' )
0164       WRITE(6,118)(NM,DES(NM),V(NM),O(NM),NM=61,70)
0165    118 FORMAT(' V(',I2, ') = ', A4,' = ',F14.5,' BARS              ',F14.5,' P
          1SIA',/,
          2' V(',I2,') = ',A4,' = ',F14.5,' BARS      ',6X,F14.5,' PSIA      ',/,
          4' V(',I2,') = ',A4,' = ',F14.5,' DEG K     ',6X,F14.5,' DEG R      ',/,
          5' V(',I2,') = ',A4,' = ',F14.5,' DEG K     ',6X,F14.5,' DEG R      ',/,
          6' V(',I2,') = ',A4,' = ',F14.5,' KG/CU.M',6X,F14.5,' LBM/CU.FT',/,
          7' V(',I2,') = ',A4,' = ',F14.5,' M/SEC     ',6X,F14.5,' FT/SEC     ',/,
          8' V(',I2,') = ',A4,' = ',F14.5,' RADIANS',6X,F14.5,' DEGREES ',/,
          9' V(',I2,') = ',A4,' = ',F14.5,' RADIANS',6X,F14.5,' DEGREES ',/,
          1' V(',I2,') = ',A4,' = ',F14.5,' SQ.M      ',6X,F14.5,' SQ.FT     ',/,
          2' V(',I2,') = ',A4,' = ',F14.5,' MW        ',6X,F14.5,' HP '     ,/)
0166       WRITE(6,119)(NM,DES(NM),V(NM),O(NM),NM=71,81)
0167    119 FORMAT(' V(',I2, ') = ', A4,' = ',F14.5,' BARS              ',F14.5,' P
          1SIA',/,
          2' V(',I2,') = ',A4,' = ',F14.5,' DEG K     ',6X,F14.5,' DEG R      ',/,
          3' V(',I2,') = ',A4,' = ',F14.5,' KG/CU.M',6X,F14.5,' LBM/CU.FT',/,
          4' V(',I2,') = ',A4,' = ',F14.5,' M/SEC     ',6X,F14.5,' FT/SEC     ',/,
          5' V(',I2,') = ',A4,' = ',F14.5,' BARS      ',6X,F14.5,' PSIA      ',/,
          6' V(',I2,') = ',A4,' = ',F14.5,' DEG K     ',6X,F14.5,' DEG R      ',/,
          7' V(',I2,') = ',A4,' = ',F14.5,' KG/CU.M',6X,F14.5,' LBM/CU.FT',/,
          8' V(',I2,') = ',A4,' = ',F14.5,' M/SEC     ',6X,F14.5,' FT/SEC     ',/,
          9' V(',I2,') = ',A4,' = ',F14.5,' J/KG-DEG K',3X,F14.5,' BTU/LBM-DE
          1G R',/,
          2' V(',I3,')= ' ,A4,' = ',F14.5,'           ',6X,F14.5,'           ',/,
          3' V(',I3,')= ' ,A4,' = ',F14.5,' SQ.M      ',6X,F14.5,' SQ.FT     ')
0168   1000 CONTINUE
0169       STOP
0170       END
```

```
      SUBROUTINE PARDIF (NVAR, V, R, PD)
      DIMENSION V(81),R(81),PD(81,81),VD(81),RD(81)
C
C   GLOSSARY FOR SUBROUTINE PARDIF
C     DV = FRACTION OF VARIABLE CHANGE USED IN TAKING PARTIAL
C     VD =  V + DELTA V  =  V + V*DV
C     RD = R EVALUATED AT VD
C     THE PARTIAL DERIVATIVE IS  (RD - R)/(V*DV)
C
      DV = 0.001
C     SETTING ALL VD = V
      DO 550  K = 1,NVAR
  550 VD(K) = V(K)
      DO 560  J = 1, NVAR
C     ADDING DELTA TO VD(J)
      VD(J) = (1. + DV)*V(J)
      CALL EQNS(NVAR, VD, RD)
      DO 558 I = 1, NVAR
      PD(I,J) = (RD(I) - R(I))/(V(J)*DV)
  558 CONTINUE
C     RETURNING VD(J) TO V(J) VALUE
      VD(J) = V(J)
  560 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GAUSSY (A, B, X, N)
C
C     SOLUTION OF SIMULTANEOUS EQUATIONS BY GAUSS ELIMINATION
C
      DIMENSION A(81,81),X(81),B(81),BC(81)
C     BEGINNING OF ELIMINATION PROCESS
      DO 28  K = 1,N
C     MOVING LARGEST COEFFICIENT INTO DIAGONAL POSITION
      AMAX = 0.
      DO 4  I = K,N
      IF(ABS(A(I,K)) - ABS(AMAX)) 4, 4, 2
    2 AMAX = A(I,K)
      IMAX = I
    4 CONTINUE
C     TESTING FOR INDEPENDENCE OF EQUATIONS
      IF(ABS(AMAX) - 0.1E-15) 10, 10, 14
   10 WRITE (6,12)
   12 FORMAT ('0 EQUATIONS ARE NOT INDEPENDENT')
      RETURN
C     EXCHANGING ROW IMAX AND ROW K
   14 BTEMP = B(K)
      B(K) = B(IMAX)
      B(IMAX) = BTEMP
      DO 18  J = K,N
      ATEMP = A(K,J)
      A(K,J) = A(IMAX, J)
   18 A(IMAX,J) = ATEMP
C     SUBTRACTING A(I,K)/A(K,K) TIMES TERM IN FIRST EQ FROM OTHERS
      KPLUS = K + 1
      IF(K - N) 22, 28, 28
   22 DO 24  I = KPLUS,N
      B(I) = B(I) - B(K)*A(I,K)/A(K,K)
      ACON = A(I,K)
      DO 24  J = K,N
   24 A(I,J) = A(I,J) - A(K,J)*ACON/A(K,K)
   28 CONTINUE
C     BACK SUBSTITUTION
      L = N
   32 SUM = 0.0
      IF(L - N) 34, 38, 38
   34 LPLUS = L + 1
      DO 36  J = LPLUS, N
   36 SUM = SUM + A(L,J)*X(J)
   38 CONTINUE
      X(L) = (B(L) - SUM)/A(L,L)
      IF(L - 1) 42, 42, 40
   40 L = L - 1
      GO TO 32
   42 RETURN
      END
```

```
      SUBROUTINE EONS(NVAR,V,R)
      DIMENSION R(81),V(81)
      COMMON A,Z,D,ALF2,ALF4,ALF6,ALF8,ALF10,BET3,BET5,BET7,BET9,BET11
      COMMON HOB1,HOB2,HOB3,HOB4,HOB5,U1,U2,U3,U4,U5,A1,A3,A5,A7,A9
      COMMON AT,ADUCT,ALF1
      COMMON ALTO,GRBE,ALTE
      R( 1)=(ALTO/((ALTE)*(GRBE)))-V( 1)
      R( 2)=V( 1)-V(30)-V(50)-V(70)
      R( 3)=1.-(.66*(((.02832/.4536)*(V( 3)/Z))**.28)*(((((.55)*((A/.304
     18)**.17))-.17)*((68.94757/V(10)) **.22))+.17))-V( 4)
      R( 4)=(((1020.*((1-V( 4))+(.075*(V(10)/68.94757))))+1535.)/1.8)-V(
     112)
      R( 5)=((V( 2))/((3.14159)*((D**2.)/4.)))-V( 3)
      R( 6)=(1.-V( 4))/(2.+V (4))-V( 5)
      R( 7)=(1.+V( 4))/(4.+2.*V( 4))-V( 6)
      R( 8)=(1.+3.*V( 4))/(4.+2.*V( 4))-V( 7)
      R( 9)=V( 5)*17.032+V( 6)*28.016+V( 7)*2.016-V( 8)
C
      R(10)=V(11)+(V(14)**2)/(2.*V(15))-V(12)
      R(11)=V( 9)+(V(13)*V(14)**2)/(2.E05)-V(10)
      R(12)=(V(16)*(8314.25/V( 8))*V(11))**.5-V(14)
      R(13)=(V(13)*(8314.25/V( 8))*V(11))/(10.**5)-V( 9)
      R(14)=V(13)*V(14)*A1-V( 2)
      R(15)=((27549.97+(25.627418)*((V(11)+V(23))/2)+.9900599E-02*((V(1
     11)+V(23))/2)**2-(.668603E-05)*((V(11)+V(23) )/2)**3+((55.5/((V(11)+
     2V(23))/2))**2)*(((V( 9)+V(21))/2)/137.89514))*V( 5)+
     3(28882.15-(1.570255)*((V(11)+V(23))/2)+(0.807512E-02)*((V(11)+V(23
     4))/2)**2-(.287064E-05)*((V(11)+V(23))/2)**3+((55.5/((V(11)+V(23))/
     52))**2)*(((V( 9)+V(21))/2)/137.89514))*V( 6)+
     6(29087.17-(1.914598)*((V(11)+V(23))/2)+(0.400116E-02)*((V(11)+V(23
     7))/2)**2-(.869854E-06)*((V(11)+V(23))/2)**3+((55.5/((V(11)+V(23))/
     82))**2)*(((V( 9)+V(21))/2)/45.965050))*V( 7))/V( 8)-V(15)
      R(16)=(V(15)/(V(15)-(8314.25/V( 8))))-V(16)
      R(17)=TAN(ALF2)+TAN(V(28))-TAN(V(27))-TAN(BET3)
      R(18)=BET3-V(27)
      R(19)=2.*V(20)*U1*TAN(BET3)/10.**4-V(19)*V(15)*V(12)*(1.-(V(22)/V(
     110))**((V(16)-1.)/V(16)))/10.**4
      R(20)=V( 2)*V(19)*V(15)*V(12)*(1.-(V(22)/V(10))**((V(16)-1.)/V(16)
     1))/(10.**6)-V(30)
      R(21)=V(12)*(1.-V(19)*(1-(V(22)/V(10))**((V(16)-1.)/V(16))))-V(24)
      R(22)=V(14)*COS(ALF2)-V(20)
      R(23)=.025*(1.+((V(27)+BET3)/1.57)**2)*(1.+(3.2/HOB1))-V(17)
      R(24)=.025*(1.+((ALF1 +ALF2)/1.57)**2)*(1.+(3.2/HOB1))-V(18)
      R(25)=1./(1.+((V(18)*(V(14)/U1)**2+V(17)*(V( 20)/(U1*COS(BET3)))**2
     1)/((2.*V(20)/U1)*(TAN(ALF2)+TAN(V(28))))))-V(19)
      R(26)=V(21)+(V(25)*V(26)**2)/(2.E05)-V(22)
      R(27)=V(23)+(V(26)**2)/(2.*V(15))-V(24)
      R(28)=(V(25)*(8314.25/V( 8))*V(23))/(10.**5)-V(21)
      R(29)=V(25)*V(26)*V(29)-V( 2)
      R(30)=V(20)/COS(V(28))-V(26)
C
      R(31)=V(32)+(V(34)**2)/(2.*V(35))-V(24)
      R(32)=V(31)+(V(33)*V(34)**2)/(2.E05)-V(22)
```

```
0039          R(33)=(V(33)*(8314.25/V( 8))*V(32))/(10.**5)-V(31)
0040          R(34)=V(33)*V(34)*A3-V( 2)
0041          R(35)=((27549.97+(25.627418)*((V(32)+V(43))/2)+.9900599E-02*((V(3
             12)+V(43))/2)**2-(.668603E-05)*((V(32)+V(43))/2)**3+((55.5/((V(32)+
             2V(43))/2))**2)*(((V(31)+V(41))/2)/137.89514))*V( 5)+
             3(28882.15-(1.570255)*((V(32)+V(43))/2)+(0.807512E-02)*((V(32)+V(43
             4))/2)**2-(.287064E-05)*((V(32)+V(43))/2)**3+((55.5/((V(32)+V(43))/
             52))**2)*(((V(31)+V(41))/2)/137.89514))*V( 6)+
             6(29087.17-(1.914598)*((V(32)+V(43))/2)+(0.400116E-02)*((V(32)+V(43
             7))/2)**2-(.869854E-06)*((V(32)+V(43))/2)**3+((55.5/((V(32)+V(43))/
             82))**2)*(((V(31)+V(41))/2)/45.965050))*V( 7))/V( 8)-V(35)
0042          R(36)=(V(35)/(V(35)-(8314.25/V( 8))))-V(36)
0043          R(37)=(U2/V(40))-(TAN(ALF4)-TAN(V(48)))
0044          R(38)=V(47)-V(48)
0045          R(39)=V(40)*U2*(TAN(ALF4)+TAN(V(48)))/10.**4-V(39)*V(35)*V(24)*(1.
             1-(V(42)/V(22))**((V(36)-1.)/V(36)))/10.**4
0046          R(40)=V( 2)*V(39)*V(35)*V(24)*(1.-(V(42)/V(22))**((V(36)-1.)/V(36)
             1))/(10.**6)-V(50)
0047          R(41)=V(24)*(1.-V(39)*(1-(V(42)/V(22))**((V(36)-1.)/V(36))))-V(44)
0048          R(42)=V(34)*COS(ALF4)-V(40)
0049          R(43)=.025*(1.+((V(47)+BET5)/1.57)**2)*(1.+(3.2/HOB2))-V(37)
0050          R(44)=.025*(1.+((V(28)+ALF4)/1.57)**2)*(1.+(3.2/HOB2))-V(38)
0051          R(45)=1./(1.+((V(38)*(V(34)/U2)**2+V(37)*(V(40)/(U2*COS(BET5)))**2
             1)/((2.*V(40)/U2)*(TAN(ALF4)+TAN(V(48))))))-V(39)
0052          R(46)=V(41)+(V(45)*V(46)**2)/(2.E05)-V(42)
0053          R(47)=V(43)+(V(46)**2)/(2.*V(35))-V(44)
0054          R(48)=(V(45)*(8314.25/V( 8))*V(43))/(10.**5)-V(41)
0055          R(49)=V(45)*V(46)*V(49)-V( 2)
0056          R(50)=V(40)/COS(V(48))-V(46)
      C
0057          R(51)=V(52)+(V(54)**2/(2.*V(55)))-V(44)
0058          R(52)=V(51)+(V(53)*V(54)**2)/(2.E05)-V(42)
0059          R(53)=(V(53)*(8314.25/V( 8))*V(52))/(10.**5)-V(51)
0060          R(54)=V(53)*V(54)*A5-V( 2)
0061          R(55)=((27549.97+(25.627418)*((V(52)+V(63))/2)+.9900599E-02*((V(5
             12)+V(63))/2)**2-(.668603E-05)*((V(52)+V(46))/2)**3+((55.5/((V(52)+
             2V(63))/2))**2)*(((V(51)+V(61))/2)/137.89514))*V( 5)+
             3(28882.15-(1.570255)*((V(52)+V(63))/2)+(0.807512E-02)*((V(52)+V(63
             4))/2)**2-(.287064E-05)*((V(52)+V(63))/2)**3+((55.5/((V(52)+V(63))/
             52))**2)*(((V(51)+V(61))/2)/137.89514))*V( 6)+
             6(29087.17-(1.914598)*((V(52)+V(63))/2)+(0.400116E-02)*((V(52)+V(63
             7))/2)**2-(.869854E-06)*((V(52)+V(63))/2)**3+((55.5/((V(52)+V(63))/
             82))**2)*(((V(51)+V(61))/2)/45.965050))*V( 7))/V( 8)-V(55)
0062          R(56)=(V(55)/(V(55)-(8314.25/V( 8))))-V(56)
0063          R(57)=(U3/V(60))-(TAN(ALF6)-TAN(V(68)))
0064          R(58)=V(67)-V(68)
0065          R(59)=V(60)*U3*(TAN(ALF6)+TAN(V(68)))/10.**4-V(59)*V(55)*V(44)*(1.
             1-(V(62)/V(42))**((V(56)-1.)/V(56)))/10.**4
0066          R(60)=V( 2)*V(59)*V(55)*V(44)*(1.-(V(62)/V(42))**((V(56)-1.)/V(56)
             1))/(10.**6)-V(70)
0067          R(61)=V(44)*(1.-V(59)*(1-(V(62)/V(42))**((V(56)-1.)/V(56))))-V(64)
0068          R(62)=V(54)*COS(ALF6)-V(60)
0069          R(63)=.025*(1.+((V(67)+BET7)/1.57)**2)*(1.+(3.2/HOB3))-V(57)
```

```
      R(64)=.025*(1.+((V(48)+ALF6)/1.57)**2)*(1.+(3.2/HOB3))-V(58)
      R(65)=1./(1.+((V(58)*(V(54)/U3)**2+V(57)*(V(60)/(U3*COS(BET7)))**2
     1)/((2.*V(60)/U2)*(TAN(ALF6)+TAN(V(68))))))-V(59)
      R(66)=V(61)+(V(65)*V(66)**2)/(2.E05)-V(62)
      R(67)=V(63)+(V(66)**2)/(2.*V(55))-V(64)
      R(68)=(V(65)*(8314.25/V( 8))*V(63))/(10.**5)-V(61)
      R(69)=V(65)*V(66)*V(69)-V( 2)
      R(70)=V(60)/COS(V(68))-V(66)
C
      R(71)=V(72)+(V(74)**2/(2.*V(79)))-V(64)
      R(72)=V(71)+(V(73)*V(74)**2)/(2.E05)-V(62)
      R(73)=(V(73)*(8314.25/V( 8))*V(72))/(10.**5)-V(71)
      R(74)=V(73)*V(74)*ADUCT-V( 2)
      R(75)=V(75)+(V(77)*V(78)**2)/(2.E05)-V(62)
      R(76)=(V( 80)*(8314.25/V( 8))*V(76))**.5-V(78)
      R(77)=(V(73)*(8314.25/V( 8))*V(76))/(10.**5)-V(75)
      R(78)=V(77)*V(78)*V( 81)-V( 2)
      R(79)=((27549.97+(25.627418)*((V(72)+V(76))/2)+.9900599E-02*((V(7
     12)+V(76))/2)**2-(.668603E-05)*((V(72)+V(76))/2)**3+((55.5/((V(72)+
     2V(76))/2))**2)*(((V(71)+V(75))/2)/137.89514))*V( 5)+
     3(28882.15-(1.570255)*((V(72)+V(76))/2)+(0.807512E-02)*((V(72)+V(76
     4))/2)**2-(.287064E-05)*((V(72)+V(76))/2)**3+((55.5/((V(72)+V(76))/
     52))**2)*(((V(71)+V(75))/2)/137.89514))*V( 6)+
     6(29087.17-(1.914598)*((V(72)+V(76))/2)+(0.400116E-02)*((V(72)+V(76
     7))/2)**2-(.869854E-06)*((V(72)+V(76))/2)**3+((55.5/((V(72)+V(76))/
     82))**2)*(((V(71)+V(75))/2)/45.965050))*V( 7))/V( 8)-V(79)
      R(80)=(V(79)/(V(79)-(8314.25/V( 8))))-V(80)
      R(81)=V(76)+(V(78)**2/(2.*V(79)))-V(64)
      RETURN
      END
```

```
NUMBER OF VARIABLES =    81
MAXIMUM FRACTION CHANGE FOR CONVERGENCE =     0.0100


VARIABLE NUMBER AND ITS TRIAL VALUE
V(  1) =  POW  =           2.33918
V(  2) = MFLO  =           2.40615
V(  3) = MFLX  =          47.48601
V(  4) =  PHI  =           0.66223
V(  5) = XNH3  =           0.12687
V(  6) =  XN2  =           0.31219
V(  7) =  XH2  =           0.56094
V(  8) =  MWT  =          12.03800
V(  9) =  P1   =          74.53757
V( 10) =  PO1  =         123.86876
V( 11) =  T1   =         964.45508
V( 12) =  TO1  =        1120.53223
V( 13) = RHO1  =          11.18985
V( 14) =  V1   =         938.99512
V( 15) =  CP1  =        2824.60083
V( 16) =  KG1  =           1.32366
V( 17) = S-R1  =           0.24222
V( 18) = S-N1  =           0.14909
V( 19) = EFF1  =           0.82226
V( 20) = VAX1  =         260.21509
V( 21) =  P2   =          54.43111
V( 22) =  PO3  =          57.29221
V( 23) =  T2   =         950.00342
V( 24) =  TO3  =         962.21338
V( 25) = RHO2  =           8.29571
V( 26) =  V2   =         262.63550
V( 27) = BET2  =           1.03000
V( 28) = ALF3  =          -0.13588
V( 29) = EFA2  =           0.00110
V( 30) = POW1  =           1.07600
V( 31) =  F3   =          44.80257
V( 32) =  T3   =         899.77344
V( 33) = RHO3  =           7.20943
V( 34) =  V3   =         588.62598
V( 35) =  CP2  =        2774.49243
V( 36) =  KG2  =           1.33144
V( 37) = S-R2  =           0.16169
V( 38) = S-N2  =           0.13204
V( 39) = EFF2  =           0.85734
V( 40) = VAX2  =         198.01688
V( 41) =  P4   =          31.11732
V( 42) =  PO5  =          32.20224
V( 43) =  T4   =         844.66382
V( 44) =  TO5  =         851.99463
V( 45) = RHO4  =           5.33396
V( 46) =  V4   =         201.69043
V( 47) = BET4  =           0.19115
V( 48) = ALF5  =         - 0.19115
V( 49) = EFA4  =           0.00224
V( 50) = POW2  =           0.73580
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```
V( 51) = P5   =     26.31075
V( 52) = T5   =    806.62500
V( 53) = RHO5 =      4.72272
V( 54) = V5   =    499.49512
V( 55) = CP3  =   2749.58350
V( 56) = KG3  =      1.33545
V( 57) = S-R3 =      0.12246
V( 58) = S-N3 =      0.16169
V( 59) = EFF3 =      0.86079
V( 60) = VAX3 =    168.03278
V( 61) = P6   =     19.80089
V( 62) = PO7  =     20.36765
V( 63) = T6   =    766.76929
V( 64) = TO7  =    772.28223
V( 65) = RHO6 =      3.73896
V( 66) = V6   =    174.11455
V( 67) = BET6 =     -0.26509
V( 68) = ALF7 =     -0.26509
V( 69) = EFA6 =      0.00370
V( 70) = POW3 =      0.52738
V( 71) = PEXD =     20.25191
V( 72) = TEXD =    771.14722
V( 73) = RHOX =      3.80241
V( 74) = VEXD =     78.02730
V( 75) = PTHT =     17.28519
V( 76) = [illegible] =    658.18262
V( 77) = P[illegible]OT =      1.00702
V( 78) = VTHT =    782.42798
V( 79) = CPEX =   2682.71362
V( 80) = KGEX =      1.34671
V( 81) = ATHT =      0.00305
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VARIABLE NUMBER AND ITS FINAL VALUE

THESE VALUES ARE FOR AN ALTERNATOR OUTPUT OF 2.00 MW

VARIABLE		VALUE(SI)	VALUE(BRITISH)
V(1) =	POW =	2.33918 MW	3136.89282 HP
V(2) =	MFLO =	2.40616 KG/SEC	5.30467 LBM/SEC
V(3) =	MFLX =	47.48625 KG/SEC-SQ.M	9.72593 LBM/SEC-SQ.FT
V(4) =	PHI =	0.66223	0.66223
V(5) =	XNH3 =	0.12687	0.12687
V(6) =	XN2 =	0.31219	0.31219
V(7) =	XH2 =	0.56094	0.56094
V(8) =	MWT =	12.03801 KG/MOLE	12.03801 LBM/MOLE
V(9) =	P1 =	74.53792 BARS	1081.08130 PSIA
V(10) =	PO1 =	123.86929 BARS	1796.57251 PSIA
V(11) =	T1 =	964.45630 DEG K	1736.02051 DEG R
V(12) =	TO1 =	1120.53320 DEG K	2016.95874 DEG R
V(13) =	RHO1 =	11.18991 KG/CU.M	0.69850 LBM/CU.FT
V(14) =	V1 =	938.99487 M/SEC	3080.69189 FT/SEC
V(15) =	CP1 =	2824.60352 J/KG-DEG K	0.67510 BTU/LBM-DEG R
V(16) =	KG1 =	1.32366	1.32366
V(17) =	S-R1 =	0.24222	0.24222
V(18) =	S-N1 =	0.14909	0.14909
V(19) =	EFF1 =	0.82226	0.82226
V(20) =	VAX1 =	260.21484 M/SEC	853.72314 FT/SEC
V(21) =	P2 =	54.43143 BARS	789.46118 PSIA
V(22) =	PO3 =	57.29251 BARS	830.95776 PSIA
V(23) =	T2 =	950.00439 DEG K	1710.00708 DEG R
V(24) =	TO3 =	962.21436 DEG K	1731.98486 DEG R
V(25) =	RHO2 =	8.29575 KG/CU.M	0.51784 LBM/CU.FT
V(26) =	V2 =	262.63550 M/SEC	861.66504 FT/SEC
V(27) =	BET2 =	1.03000 RADIANS	59.01897 DEGREES
V(28) =	ALF3 =	-0.13588 RADIANS	-7.78581 DEGREES
V(29) =	EFA2 =	0.00110 SQ.M	0.01189 SQ.FT
V(30) =	POW1 =	1.07600 MW	1442.94482 HP
V(31) =	P3 =	44.80284 BARS	649.81030 PSIA
V(32) =	T3 =	899.77466 DEG K	1619.59351 DEG R
V(33) =	RHO3 =	7.20948 KG/CU.M	0.45003 LBM/CU.FT
V(34) =	V3 =	588.62476 M/SEC	1931.18359 FT/SEC
V(35) =	CP2 =	2774.49609 J/KG-DEG K	0.66312 BTU/LBM-DEG R
V(36) =	KG2 =	1.33144	1.33144
V(37) =	S-R2 =	0.16169	0.16169
V(38) =	S-N2 =	0.13204	0.13204
V(39) =	EFF2 =	0.85734	0.85734
V(40) =	VAX2 =	198.01649 M/SEC	649.66040 FT/SEC
V(41) =	P4 =	31.11761 BARS	451.32275 PSIA
V(42) =	PO5 =	32.20251 BARS	467.05811 PSIA
V(43) =	T4 =	844.66528 DEG K	1520.39673 DEG R
V(44) =	TO5 =	851.99609 DEG K	1533.59229 DEG R
V(45) =	RHO4 =	5.33401 KG/CU.M	0.33296 LBM/CU.FT
V(46) =	V4 =	201.68987 M/SEC	661.71216 FT/SEC
V(47) =	BET4 =	0.19115 RADIANS	10.95272 DEGREES
V(48) =	ALF5 =	0.19115 RADIANS	10.95272 DEGREES
V(49) =	EFA4 =	0.00224 SQ.M	0.02407 SQ.FT

V(50) = POW2 =	0.73580	MW	986.73047	HP
V(51) = P5 =	26.31107	BARS	381.60962	PSIA
V(52) = T5 =	806.62720	DEG K	1451.92822	DEG R
V(53) = RHO5 =	4.72277	KG/CU.M	0.29481	LBM/CU.FT
V(54) = V5 =	499.49121	M/SEC	1638.750[illegible]3	FT/SEC
V(55) = CP3 =	2749.58594	J/KG-DEG K	0.65717	BTU/LBM-DEG R
V(56) = KG3 =	1.33545		1.33545	
V(57) = S-R3 =	0.12246		0.12246	
V(58) = S-N3 =	0.16169		0.16169	
V(59) = EFF3 =	0.86079		0.86079	
V(60) = VAX3 =	168.03148	M/SEC	551.28442	FT/SEC
V(61) = P6 =	19.80138	BARS	287.19458	PSIA
V(62) = PO7 =	20.36813	BARS	295.41479	PSIA
V(63) = T6 =	766.77124	DEG K	1380.18750	DEG R
V(64) = TO7 =	772.28394	DEG K	1390.11035	DEG R
V(65) = RHO6 =	3.73905	KG/CU.M	0.23340	LBM/CU.FT
V(66) = V6 =	174.11438	M/SEC	571.24121	FT/SEC
V(67) = BET6 =	-0.26511	RADIANS	-15.19081	DEGREES
V(68) = ALF7 =	-0.26511	RADIANS	-15.19081	DEGREES
V(69) = EFA6 =	0.00370	SQ.M	0.03978	SQ.FT
V(70) = POW3 =	0.52737	MW	707.21655	HP
V(71) = PEXD =	20.25240	BARS	293.73608	PSIA
V(72) = TEXD =	771.14941	DEG K	1388.06812	DEG R
V(73) = RHOX =	3.80251	KG/CU.M	0.23736	LBM/CU.FT
V(74) = VEXD =	78.02518	M/SEC	255.98813	FT/SEC
V(75) = PTHT =	17.28563	BARS	250.70692	PSIA
V(76) = TTHT =	658.18384	DEG K	1184.73022	DEG R
V(77) = RHOT =	1.00704	KG/CU.M	0.06286	LBM/CU.FT
V(78) = VTHT =	782.42920	M/SEC	2567.02515	FT/SEC
V(79) = CPEX =	2682.71533	J/KG-DEG K	0.64118	BTU/LBM-DEG R
V(80)= KGEX =	1.34671		1.34671	
V(81)= ATHT =	0.00305	SQ.M	0.03287	SQ.FT

NUMBER OF VARIABLES = 81
MAXIMUM FRACTION CHANGE FOR CONVERGENCE = 0.0100

VARIABLE NUMBER ANO ITS TRIAL VALUE

V(1) =	POW =	2.33918
V(2) =	MFLO =	2.40616
V(3) =	MFLX =	47.48625
V(4) =	PHI =	0.66223
V(5) =	XNH3 =	0.12687
V(6) =	XN2 =	0.31219
V(7) =	XH2 =	0.56094
V(8) =	MWT =	12.03801
V(9) =	P1 =	74.53792
V(10) =	P01 =	123.86929
V(11) =	T1 =	964.45630
V(12) =	T01 =	1120.53320
V(13) =	RHO1 =	11.18991
V(14) =	V1 =	938.99487
V(15) =	CP1 =	2824.60352
V(16) =	KG1 =	1.32366
V(17) =	S-R1 =	0.24222
V(18) =	S-N1 =	0.14909
V(19) =	EFF1 =	0.82226
V(20) =	VAX1 =	260.21484
V(21) =	P2 =	54.43143
V(22) =	P03 =	57.29251
V(23) =	T2 =	950.00439
V(24) =	T03 =	962.21436
V(25) =	RHO2 =	8.29575
V(26) =	V2 =	262.63550
V(27) =	BET2 =	1.03000
V(28) =	ALF3 =	-0.13588
V(29) =	EFA2 =	0.00110
V(30) =	POW1 =	1.07600
V(31) =	P3 =	44.80284
V(32) =	T3 =	899.77466
V(33) =	RHO3 =	7.20948
V(34) =	V3 =	588.62476
V(35) =	CP2 =	2774.49609
V(36) =	KG2 =	1.33144
V(37) =	S-R2 =	0.16169
V(38) =	S-N2 =	0.13204
V(39) =	EFF2 =	0.85734
V(40) =	VAX2 =	198.01649
V(41) =	P4 =	31.11761
V(42) =	P05 =	32.20251
V(43) =	T4 =	844.66528
V(44) =	T05 =	851.99609
V(45) =	RHO4 =	5.33401
V(46) =	V4 =	201.68987
V(47) =	BET4 =	0.19115
V(48) =	ALF5 =	0.19115
V(49) =	EFA4 =	0.00224
V(50) =	POW2 =	0.73580

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V( 51) =  P5   =      26.31107
V( 52) =  T5   =     806.62720
V( 53) = RHO5  =       4.72277
V( 54) =  V5   =     499.49121
V( 55) =  CP3  =    2749.58594
V( 56) =  KG3  =       1.33545
V( 57) = S-R3  =       0.12246
V( 58) = S-N3  =       0.16169
V( 59) = EFF3  =       0.86079
V( 60) = VAX3  =     168.03148
V( 61) =  P6   =      19.80138
V( 62) =  PO7  =      20.36813
V( 63) =  T6   =     765.77124
V( 64) =  TO7  =     772.28394
V( 65) = RHO6  =       3.73905
V( 66) =  V6   =     174.11438
V( 67) = BET6  =      -0.26511
V( 68) = ALF7  =      -0.26511
V( 69) = EFA6  =       0.00370
V( 70) = POH3  =       0.52737
V( 71) = PEXD  =      20.25240
V( 72) = TEXD  =     771.14941
V( 73) = RHOX  =       3.80251
V( 74) = VEXD  =      78.02518
V( 75) = PTHT  =      17.28563
V( 76) = TTHT  =     658.18384
V( 77) = RHOT  =       1.00704
V( 78) = VTHT  =     782.42920
V( 79) = CPEX  =    2682.71533
V( 80) = KGEX  =       1.34671
V( 81) = ATHT  =       0.00305
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VARIABLE NUMBER AND ITS FINAL VALUE

THESE VALUES ARE FOR AN ALTERNATOR OUTPUT OF 1.60 MW

VARIABLE	VALUE(SI)	VALUE(BRITISH)
V(1) = PDW =	1.87134 MW	2509.51270 HP
V(2) = MFLO =	1.92066 KG/SEC	4.23432 LBM/SEC
V(3) = MFLX =	37.90465 KG/SEC-SQ.M	7.76346 LBM/SEC-SQ.FT
V(4) = PHI =	0.67791	0.67791
V(5) = XNH3 =	0.12028	0.12028
V(6) = XN2 =	0.31329	0.31329
V(7) = XH2 =	0.56643	0.56643
V(8) = MWT =	11.96755 KG/MOLE	11.96755 LBM/MOLE
V(9) = P1 =	58.86128 BARS	853.71094 PSIA
V(10) = PD1 =	97.94031 BARS	1420.50439 PSIA
V(11) = T1 =	941.36304 DEG K	1694.45264 DEG R
V(12) = TO1 =	1095.66870 DEG K	1972.20264 DEG R
V(13) = RHO1 =	9.00026 KG/CU.M	0.56181 LBM/CU.FT
V(14) = V1 =	931.87866 M/SEC	3057.34473 FT/SEC
V(15) = CP1 =	2813.89038 J/KG-DEG K	0.67254 BTU/LBM-DEG R
V(16) = KG1 =	1.32783	1.32783
V(17) = S-R1 =	0.24222	0.24222
V(18) = S-N1 =	0.14909	0.14909
V(19) = EFF1 =	0.82337	0.82337
V(20) = VAX1 =	258.24268 M/SEC	847.25293 FT/SEC
V(21) = P2 =	42.71643 BARS	619.54956 PSIA
V(22) = PO3 =	44.97217 BARS	652.26611 PSIA
V(23) = T2 =	925.88037 DEG K.	1666.58374 DEG R
V(24) = TO3 =	937.95166 DEG K	1688.31226 DEG R
V(25) = RHO2 =	6.64084 KG/CU.M	0.41453 LBM/CU.FT
V(26) = V2 =	260.64502 M/SEC	855.13452 FT/SEC
V(27) = BET2 =	1.03000 RADIANS	59.01897 DEGREES
V(28) = ALF3 =	-0.13588 RADIANS	-7.78581 DEGREES
V(29) = EFA2 =	0.00111 SQ.M	0.01194 SQ.FT
V(30) = POW1 =	0.85238 MW	1143.06470 HP
V(31) = P3 =	35.00558 BARS	507.71313 PSIA
V(32) = T3 =	875.31250 DEG K	1575.56177 DEG R
V(33) = RHO3 =	5.75647 KG/CU.M	0.35933 LBM/CU.FT
V(34) = V3 =	588.45093 M/SEC	1930.61328 FT/SEC
V(35) = CP2 =	2764.04565 J/KG-DEG K	0.66062 BTU/LBM-DEG R
V(36) = KG2 =	1.33573	1.33573
V(37) = S-R2 =	0.16161	0.16161
V(38) = S-N2 =	0.13204	0.13204
V(39) = EFF2 =	0.85737	0.85737
V(40) = VAX2 =	197.95799 M/SEC	649.46851 FT/SEC
V(41) = P4 =	24.10658 BARS	349.63647 PSIA
V(42) = PO5 =	24.96648 BARS	362.10815 PSIA
V(43) = T4 =	820.02588 DEG K	1476.04590 DEG R
V(44) = TO5 =	827.37769 DEG K	1489.27905 DEG R
V(45) = RHO4 =	4.23147 KG/CU.M	0.26414 LBM/CU.FT
V(46) = V4 =	201.60138 M/SEC	661.42188 FT/SEC
V(47) = BET4 =	0.19040 RADIANS	10.91018 DEGREES
V(48) = ALF5 =	0.19040 RADIANS	10.91018 DEGREES
V(49) = EFA4 =	0.00225 SQ.M	0.02423 SQ.FT

V(50) = POW2 =	0.58701	MW	787.19580	HP
V(51) = P5 =	20.20836	BARS	293.09741	PSIA
V(52) = T5 =	780.69165	DEG K	1405.24414	DEG R
V(53) = RHO5 =	3.72592	KG/CU.M	0.23258	LBM/CU.FT
V(54) = V5 =	505.37744	M/SEC	1658.06250	FT/SEC
V(55) = CP3 =	2735.35205	J/KG-DEG K	0.65376	BTU/LBM-DEG R
V(56) = KG3 =	1.34045		1.34045	
V(57) = S-R3 =	0.12483		0.12483	
V(58) = S-N3 =	0.16161		0.16161	
V(59) = EFF3 =	0.86010		0.86010	
V(60) = VAX3 =	170.01160	M/SEC	557.78076	FT/SEC
V(61) = P6 =	14.95262	BARS	216.86946	PSIA
V(62) = P07 =	15.39656	BARS	223.30832	PSIA
V(63) = T6 =	739.58252	DEG K	1331.24780	DEG R
V(64) = T07 =	745.15942	DEG K	1341.28638	DEG R
V(65) = RHO6 =	2.91013	KG/CU.M	0.18166	LBM/CU.FT
V(66) = V6 =	174.67152	M/SEC	573.06934	FT/SEC
V(67) = BET6 =	-0.23151	RADIANS	-13.26534	DEGREES
V(68) = ALF7 =	-0.23151	RADIANS	-13.26534	DEGREES
V(69) = EFA6 =	0.00378	SQ.M	0.04067	SQ.FT
V(70) = POW3 =	0.43195	MW	579.25098	HP
V(71) = PEXD =	15.30184	BARS	221.93449	PSIA
V(72) = TEXD =	743.96313	DEG K	1339.13306	DEG R
V(73) = RHOX =	2.96056	KG/CU.M	0.18480	LBM/CU.FT
V(74) = VEXD =	79.99350	M/SEC	262.44580	FT/SEC
V(75) = PTHT =	13.03802	BARS	189.10060	PSIA
V(76) = TTHT =	633.89819	DEG K	1141.01611	DEG R
V(77) = RHOT =	0.79281	KG/CU.M	0.04949	LBM/CU.FT
V(78) = VTHT =	771.35156	M/SEC	2530.68115	FT/SEC
V(79) = CPEX =	2673.81494	J/KG-DEG K	0.63906	BTU/LBM-DEG R
V(80)= KGEX =	1.35104		1.35104	
V(81)= ATHT =	0.00314	SQ.M	0.03381	SQ.FT

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NUMBER OF VARIABLES =    81
MAXIMUM FRACTION CHANGE FOR CONVERGENCE =     0.0100


VARIABLE NUMBER AND ITS TRIAL VALUE
V(  1) =  POW =         1.87134
V(  2) = MFLO =         1.92066
V(  3) = MFLX =        37.90465
V(  4) =  PHI =         0.67791
V(  5) = XNH3 =         0.12028
V(  6) =  XN2 =         0.31329
V(  7) =  XH2 =         0.56643
V(  8) =  MWT =        11.96755
V(  9) =  P1  =        58.86128
V( 10) =  PO1 =        97.94031
V( 11) =  T1  =       941.36304
V( 12) =  TO1 =      1095.66870
V( 13) = RHO1 =         9.00026
V( 14) =  V1  =       931.87866
V( 15) =  CP1 =      2813.89038
V( 16) =  KG1 =         1.32783
V( 17) = S-R1 =         0.24222
V( 18) = S-N1 =         0.14909
V( 19) = EFF1 =         0.82337
V( 20) = VAX1 =       258.24268
V( 21) =  P2  =        42.71643
V( 22) =  PO3 =        44.97217
V( 23) =  T2  =       925.88037
V( 24) =  TO3 =       937.95166
V( 25) = RHO2 =         6.64084
V( 26) =  V2  =       260.64502
V( 27) = BET2 =         1.03000
V( 28) = ALF3 =        -0.13588
V( 29) = EFA2 =         0.00111
V( 30) = POW1 =         0.85238
V( 31) =  P3  =        35.00558
V( 32) =  T3  =       875.31250
V( 33) = RHO3 =         5.75647
V( 34) =  V3  =       588.45093
V( 35) =  CP2 =      2764.04565
V( 36) =  KG2 =         1.33573
V( 37) = S-R2 =         0.16161
V( 38) = S-N2 =         0.13204
V( 39) = EFF2 =         0.85737
V( 40) = VAX2 =       197.95799
V( 41) =  P4  =        24.10658
V( 42) =  PO5 =        24.96648
V( 43) =  T4  =       820.02588
V( 44) =  TO5 =       827.37769
V( 45) = RHO4 =         4.23147
V( 46) =  V4  =       201.60138
V( 47) = BET4 =         0.19040
V( 48) = ALF5 =         0.19040
V( 49) = EFA4 =         0.00225
V( 50) = POW2 =         0.58701
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V(51) =	P5 =	20.20836
V(52) =	T5 =	780.69165
V(53) =	RHO5 =	3.72592
V(54) =	V5 =	505.37744
V(55) =	CP3 =	2735.35205
V(56) =	KG3 =	1.34045
V(57) =	S-R3 =	0.12483
V(58) =	S-N3 =	0.16161
V(59) =	EFF3 =	0.86010
V(60) =	VAX3 =	170.01160
V(61) =	P6 =	14.95262
V(62) =	PO7 =	15.39656
V(63) =	T6 =	739.58252
V(64) =	TO7 =	745.15942
V(65) =	RHO6 =	2.91013
V(66) =	V6 =	174.67152
V(67) =	BET6 =	-0.23151
V(68) =	ALF7 =	-0.23151
V(69) =	EFA6 =	0.00378
V(70) =	POW3 =	0.43195
V(71) =	PEXD =	15.30184
V(72) =	TEXD =	743.96313
V(73) =	RHOX =	2.96056
V(74) =	VEXD =	79.99350
V(75) =	PTHT =	13.03802
V(76) =	TTHT =	633.89819
V(77) =	RHOT =	0.79281
V(78) =	VTHT =	771.35156
V(79) =	CPEX =	2673.81494
V(80) =	KGEX =	1.35104
V(81) =	ATHT =	0.00314

VARIABLE NUMBER AND ITS FINAL VALUE

THESE VALUES ARE FOR AN ALTERMATOR OUTPUT OF 1.20 MW

VARIABLE	VALUE(SI)	VALUE(BRITISH)
V(1) = POW =	1.40351 MW	1882.13501 HP
V(2) = MFLO =	1.43582 KG/SEC	3.16544 LBM/SEC
V(3) = MFLX =	28.33632 KG/SEC-SQ.M	5.80372 LBM/SEC-SQ.FT
V(4) = PHI =	0.69686	0.69686
V(5) = XNH3 =	0.11240	0.11240
V(6) = XN2 =	0.31460	0.31460
V(7) = XH2 =	0.57300	0.57300
V(8) = MWT =	11.88343 KG/MOLE	11.88343 LBM/MOLE
V(9) = P1 =	43.50079 BARS	630.92578 PSIA
V(10) = P01 =	72.48459 BARS	1051.30029 PSIA
V(11) = T1 =	916.79028 DEG K	1650.22168 DEG R
V(12) = T01 =	1069.23584 DEG K	1924.62354 DEG R
V(13) = RHO1 =	6.78182 KG/CU.M	0.42333 LBM/CU.FT
V(14) = V1 =	924.52661 M/SEC	3033.22388 FT/SEC
V(15) = CP1 =	2803.45947 J/KG-DEG K	0.67004 BTU/LBM-DEG R
V(16) = KG1 =	1.33256	1.33256
V(17) = S-R1 =	0.24222	0.24222
V(18) = S-N1 =	0.14909	0.14909
V(19) = EFF1 =	0.82451	0.82451
V(20) = VAX1 =	256.20557 M/SEC	840.56934 FT/SEC
V(21) = P2 =	31.35936 BARS	454.82910 PSIA
V(22) = P03 =	33.02396 BARS	478.97192 PSIA
V(23) = T2 =	900.25488 DEG K	1620.45801 DEG R
V(24) = T03 =	912.18066 DEG K	1641.92432 DEG R
V(25) = RHO2 =	4.97875 KG/CU.M	0.31078 LBM/CU.FT
V(26) = V2 =	258.58887 M/SEC	848.38867 FT/SEC
V(27) = BET2 =	1.03000 RADIANS	59.01897 DEGREES
V(28) = ALF3 =	-0.13588 RADIANS	-7.78581 DEGREES
V(29) = EFA2 =	0.00112 SQ.M	0.01200 SQ.FT
V(30) = POW1 =	0.63219 MW	847.77856 HP
V(31) = P3 =	25.57379 BARS	370.91650 PSIA
V(32) = T3 =	849.32617 DEG K	1528.78638 DEG R
V(33) = RHO3 =	4.30367 KG/CU.M	0.26864 LBM/CU.FT
V(34) = V3 =	588.40820 M/SEC	1930.47314 FT/SEC
V(35) = CP2 =	2754.15894 J/KG-DEG K	0.65826 BTU/LBM-DEG R
V(36) = KG2 =	1.34054	1.34054
V(37) = S-R2 =	0.16159	0.16159
V(38) = S-N2 =	0.13204	0.13204
V(39) = EFF2 =	0.85738	0.85738
V(40) = VAX2 =	197.94360 M/SEC	649.42114 FT/SEC
V(41) = P4 =	17.44447 BARS	253.01076 PSIA
V(42) = P05 =	18.08258 BARS	262.26563 PSIA
V(43) = T4 =	793.84839 DEG K	1428.92627 DEG R
V(44) = T05 =	801.22510 DEG K	1442.20435 DEG R
V(45) = RHO4 =	3.14079 KG/CU.M	0.19605 LBM/CU.FT
V(46) = V4 =	201.57959 M/SEC	661.35034 FT/SEC
V(47) = BET4 =	0.19022 RADIANS	10.89970 DEGREES
V(48) = ALF5 =	0.19022 RADIANS	10.89970 DEGREES
V(49) = EFA4 =	0.00227 SQ.M	0.02441 SQ.FT

V(50) =	POW2 =	0.43877	MW	588.40308	HP
V(51) =	P5 =	14.47696	BARS	209.97063	PSIA
V(52) =	T5 =	753.01855	DEG K	1355.43262	DEG R
V(53) =	RHO5 =	2.74783	KG/CU.M	0.17153	LBM/CU.FT
V(54) =	V5 =	512.28345	M/SEC	1680.71997	FT/SEC
V(55) =	CP3 =	2721.97559	J/KG-DEG K	0.65057	BTU/LBM-DEG R
V(56) =	KG3 =	1.34596		1.34596	
V(57) =	S-R3 =	0.12770		0.12770	
V(58) =	S-N3 =	0.16159		0.16159	
V(59) =	EFF3 =	0.85918		0.85918	
V(60) =	VAX3 =	172.33487	M/SEC	565.40308	FT/SEC
V(61) =	P6 =	10.49730	BARS	152.25055	PSIA
V(62) =	PO7 =	10.82280	BARS	156.97144	PSIA
V(63) =	T6 =	710.47461	DEG K	1278.85352	DEG R
V(64) =	TO7 =	716.13696	DEG K	1289.04590	DEG R
V(65) =	RHO6 =	2.11178	KG/CU.M	0.13182	LBM/CU.FT
V(66) =	V6 =	175.57477	M/SEC	576.03271	FT/SEC
V(67) =	BET6 =	-0.19241	RADIANS	-11.02494	DEGREES
V(68) =	ALF7 =	-0.19241	RADIANS	-11.02494	DEGREES
V(69) =	EFA6 =	0.00387	SQ.M	0.04168	SQ.FT
V(70) =	POW3 =	0.33255	MW	445.95313	HP
V(71) =	PEXD =	10.74988	BARS	155.91385	PSIA
V(72) =	TEXD =	714.86450	DEG K	1286.75537	DEG R
V(73) =	RHOX =	2.14931	KG/CU.M	0.13416	LBM/CU.FT
V(74) =	VEXD =	82.37239	M/SEC	270.25049	FT/SEC
V(75) =	PTHT =	9.14250	BARS	132.60077	PSIA
V(76) =	TTHT =	607.97388	DEG K	1094.35229	DEG R
V(77) =	RHOT =	0.58271	KG/CU.M	0.03637	LBM/CU.FT
V(78) =	VTHT =	759.42236	M/SEC	2491.54321	FT/SEC
V(79) =	CPEX =	2665.98145	J/KG-DEG K	0.63718	BTU/LBM-DEG R
V(80)=	KGEX =	1.35581		1.35581	
V(81)=	ATHT =	0.00324	SQ.M	0.03493	SQ.FT

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NUMBER OF VARIABLES =    81
MAXIMUM FRACTION CHANGE FOR CONVERGENCE =     0.0100


VARIABLE NUMBER AND ITS TRIAL VALUE
V(  1) =  POW  =         1.40351
V(  2) = MFLO  =         1.43582
V(  3) = MFLX  =        28.33632
V(  4) =  PHI  =         0.69686
V(  5) = XNH3  =         0.11240
V(  6) =  XN2  =         0.31460
V(  7) =  XH2  =         0.57300
V(  8) =  MWT  =        11.88343
V(  9) =  P1   =        43.50079
V( 10) =  PO1  =        72.48459
V( 11) =  T1   =       916.79028
V( 12) =  TO1  =      1069.23584
V( 13) = RHO1  =         6.78182
V( 14) =  V1   =       924.52661
V( 15) =  CP1  =      2803.45947
V( 16) =  KG1  =         1.33256
V( 17) = S-R1  =         0.24222
V( 18) = S-N1  =         0.14909
V( 19) = EFF1  =         0.82451
V( 20) = VAX1  =       256.20557
V( 21) =  P2   =        31.35936
V( 22) =  PO3  =        33.02396
V( 23) =  T2   =       900.25488
V( 24) =  TO3  =       912.18066
V( 25) = RHO2  =         4.97875
V( 26) =  V2   =      25[illegible].58887
V( 27) = BET2  =         1.03000
V( 28) = ALF3  =        -0.13588
V( 29) = EFA2  =         0.00112
V( 30) = POW1  =         0.63219
V( 31) =  P3   =        25.57379
V( 32) =  T3   =       849.32617
V( 33) = RHO3  =         4.30367
V( 34) =  V3   =       588.40820
V( 35) =  CP2  =      2754.15894
V( 36) =  KG2  =         1.34054
V( 37) = S-R2  =         0.16159
V( 38) = S-N2  =         0.13204
V( 39) = EFF2  =         0.85738
V( 40) = VAX2  =       197.94360
V( 41) =  P4   =        17.44447
V( 42) =  PO5  =        18.08258
V( 43) =  T4   =       793.84839
V( 44) =  TO5  =       801.22510
V( 45) = RHO4  =         3.14079
V( 46) =  V4   =       201.57959
V( 47) = BET4  =         0.19022
V( 48) = ALF5  =         0.19022
V( 49) = EFA4  =         0.00227
V( 50) = POW2  =         0.43877
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V( 51) =  P5   =      14.47696
V( 52) =  T5   =     753.01855
V( 53) = RHO5  =       2.74783
V( 54) =  V5   =     512.28345
V( 55) =  CP3  =    2721.97559
V( 56) =  KG3  =       1.34596
V( 57) = S-R3  =       0.12770
V( 58) = S-N3  =       0.16159
V( 59) = EFF3  =       0.85918
V( 60) = VAX3  =     172.33487
V( 61) =  P6   =      10.49730
V( 62) =  PO7  =      10.82280
V( 63) =  T6   =     710.47461
V( 64) =  TO7  =     716.13696
V( 65) = RHO6  =       2.11178
V( 66) =  V6   =     175.57477
V( 67) = BET6  =      -0.19241
V( 68) = ALF7  =      -0.19241
V( 69) = EFA6  =       0.00387
V( 70) = POW3  =       0.33255
V( 71) = PEXD  =      10.74988
V( 72) = TEXD  =     714.86450
V( 73) = RHOX  =       2.14931
V( 74) = VEXD  =      82.37239
V( 75) = PTHT  =       9.14250
V( 76) = TTHT  =     607.97388
V( 77) = RHOT  =       0.58271
V( 78) = VTHT  =     759.42236
V( 79) = CPEX  =    2665.98145
V( 80) = KGEX  =       1.35581
V( 81) = ATHT  =       0.00324
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VARIABLE NUMBER AND ITS FINAL VALUE

THESE VALUES ARE FOR AN ALTERNATOR OUTPUT OF 0.80 MW

VARIABLE	VALUE(SI)	VALUE(BRITISH)
V(1) = POW =	0.93567 MW	1254.75757 HP
V(2) = MFLO =	0.95267 KG/SEC	2.10028 LBM/SEC
V(3) = MFLX =	18.80127 KG/SEC-SQ.M	3.85079 LBM/SEC-SQ.FT
V(4) = PHI =	0.72132	0.72132
V(5) = XNH3 =	0.10240	0.10240
V(6) = XN2 =	0.31627	0.31627
V(7) = XH2 =	0.58133	0.58133
V(8) = MWT =	11.77661 KG/MOLE	11.77661 LBM/MOLE
V(9) = P1 =	28.49974 BARS	413.35376 PSIA
V(10) = P01 =	47.56911 BARS	689.93164 PSIA
V(11) = T1 =	889.58203 DEG K	1601.24683 DEG R
V(12) = T01 =	1040.01636 DEG K	1872.02856 DEG R
V(13) = RHO1 =	4.53787 KG/CU.M	0.28326 LBM/CU.FT
V(14) = V1 =	916.76270 M/SEC	3007.75171 FT/SEC
V(15) = CP1 =	2793.42432 J/KG-DEG K	0.66764 BTU/LBM-DEG R
V(16) = KG1 =	1.33821	1.33821
V(17) = S-R1 =	0.24222	0.24222
V(18) = S-N1 =	0.14909	0.14909
V(19) = EFF1 =	0.82573	0.82573
V(20) = VAX1 =	254.05411 M/SEC	833.51074 FT/SEC
V(21) = P2 =	20.39499 BARS	295.80420 PSIA
V(22) = P03 =	21.48415 BARS	311.60107 PSIA
V(23) = T2 =	871.95215 DEG K	1569.51318 DEG R
V(24) = T03 =	883.72070 DEG K	1590.69653 DEG R
V(25) = RHO2 =	3.31306 KG/CU.M	0.20681 LBM/CU.FT
V(26) = V2 =	256.41748 M/SEC	841.26465 FT/SEC
V(27) = BET2 =	1.03000 RADIANS	59.01897 DEGREES
V(28) = ALF3 =	-0.13588 RADIANS	-7.78581 DEGREES
V(29) = EFA2 =	0.00112 SQ.M	0.01207 SQ.FT
V(30) = POW1 =	0.41594 MW	557.78052 HP
V(31) = P3 =	16.53975 BARS	239.88884 PSIA
V(32) = T3 =	820.62891 DEG K	1477.13135 DEG R
V(33) = RHO3 =	2.85483 KG/CU.M	0.17820 LBM/CU.FT
V(34) = V3 =	588.54761 M/SEC	1930.93042 FT/SEC
V(35) = CP2 =	2745.11304 J/KG-DEG K	0.65610 BTU/LBM-DEG R
V(36) = KG2 =	1.34623	1.34623
V(37) = S-R2 =	0.16165	0.16165
V(38) = S-N2 =	0.13204	0.13204
V(39) = EFF2 =	0.85735	0.85735
V(40) = VAX2 =	197.99052 M/SEC	649.57520 FT/SEC
V(41) = P4 =	11.15817 BARS	161.83556 PSIA
V(42) = P05 =	11.57824 BARS	167.92827 PSIA
V(43) = T4 =	764.94360 DEG K	1376.89771 DEG R
V(44) = T05 =	772.34985 DEG K	1390.22900 DEG R
V(45) = RHO4 =	2.06615 KG/CU.M	0.12897 LBM/CU.FT
V(46) = V4 =	201.65057 M/SEC	661.58325 FT/SEC
V(47) = BET4 =	0.19082 RADIANS	10.93385 DEGREES
V(48) = ALF5 =	0.19082 RADIANS	10.93385 DEGREES
V(49) = EFA4 =	0.00229 SQ.M	0.02461 SQ.FT

V(50) = POW2 =	0.29126	MW	390.58130	HP
V(51) = P5 =	9.14639	BARS	132.65717	PSIA
V(52) = T5 =	722.31336	DEG K	1300.16455	DEG R
V(53) = RHO5 =	1.79358	KG/CU.M	0.11196	LBM/CU.FT
V(54) = V5 =	520.74292	M/SEC	1708.47412	FT/SEC
V(55) = CP3 =	2709.78857	J/KG-DEG K	0.64766	BTU/LBM-DEG R
V(56) = KG3 =	1.35233		1.35233	
V(57) = S-R3 =	0.13131		0.13131	
V(58) = S-N3 =	0.16165		0.16165	
V(59) = EFF3 =	0.85791		0.85791	
V(60) = VAX3 =	175.18066	M/SEC	574.73975	FT/SEC
V(61) = P6 =	6.46630	BARS	93.78574	PSIA
V(62) = P07 =	6.67799	BARS	96.85611	PSIA
V(63) = T6 =	678.06128	DEG K	1220.50977	DEG R
V(64) = T07 =	683.84497	DEG K	1230.92041	DEG R
V(65) = RHO6 =	1.35078	KG/CU.M	0.08432	LBM/CU.FT
V(66) = V6 =	177.04234	M/SEC	580.84741	FT/SEC
V(67) = BET6 =	-0.14515	RADIANS	-8.31713	DEGREES
V(68) = ALF7 =	-0.14515	RADIANS	-8.31713	DEGREES
V(69) = EFA6 =	0.00398	SQ.M	0.04288	SQ.FT
V(70) = POW3 =	0.22848	MW	306.39526	HP
V(71) = PEXD =	6.62783	BARS	96.12863	PSIA
V(72) = TEXD =	682.47412	DEG K	1228.45288	DEG R
V(73) = RHOX =	1.37557	KG/CU.M	0.08587	LBM/CU.FT
V(74) = VEXD =	85.39653	M/SEC	280.17236	FT/SEC
V(75) = PTHT =	5.62490	BARS	81.58223	PSIA
V(76) = TTHT =	579.20068	DEG K	1042.56055	DEG R
V(77) = RHOT =	0.37836	KG/CU.M	0.02362	LBM/CU.FT
V(78) = VTHT =	746.10352	M/SEC	2447.84619	FT/SEC
V(79) = CPEX =	2659.82422	J/KG-DEG K	0.63571	BTU/LBM-DEG R
V(80)= KGEX =	1.36134		1.36134	
V(81)= ATHT =	0.00337	SQ.M	0.03633	SQ.FT

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NUMBER OF VARIABLES =   81
MAXIMUM FRACTION CHANGE FOR CONVERGENCE =     0.0100


VARIABLE NUMBER AND ITS TRIAL VALUE
V(  1) =  POW  =          0.93567
V(  2) = MFLO  =          0.95267
V(  3) = MFLX  =         18.80127
V(  4) =  PHI  =          0.72132
V(  5) = XNH3  =          0.10240
V(  6) =  XN2  =          0.31627
V(  7) =  XH2  =          0.58133
V(  8) =  MWT  =         11.77661
V(  9) =  P1   =         28.49974
V( 10) =  PO1  =         47.56911
V( 11) =  T1   =        889.58203
V( 12) =  TO1  =       1040.01636
V( 13) = RHO1  =          4.53787
V( 14) =  V1   =        916.76270
V( 15) =  CP1  =       2793.42432
V( 16) =  KG1  =          1.33821
V( 17) = S-R1  =          0.24222
V( 18) = S-N1  =          0.14909
V( 19) = EFF1  =          0.82573
V( 20) = VAX1  =        254.05411
V( 21) =  P2   =         20.39499
V( 22) =  PO3  =         21.48415
V( 23) =  T2   =        871.95215
V( 24) =  TO3  =        883.72070
V( 25) = RHO2  =          3.31306
V( 26) =  V2   =        256.41748
V( 27) = BET2  =          1.03000
V( 28) = ALF3  =         -0.13588
V( 29) = EFA2  =          0.00112
V( 30) = POW1  =          0.41594
V( 31) =  P3   =         16.53975
V( 32) =  T3   =        820.62891
V( 33) = RHO3  =          2.85483
V( 34) =  V3   =        588.54761
V( 35) =  CP2  =       2745.11304
V( 36) =  KG2  =          1.34623
V( 37) = S-R2  =          0.16165
V( 38) = S-N2  =          0.13204
V( 39) = EFF2  =          0.85735
V( 40) = VAX2  =        197.99052
V( 41) =  P4   =         11.15817
V( 42) =  PO5  =         11.57824
V( 43) =  T4   =        764.94360
V( 44) =  TO5  =        772.34985
V( 45) = RHO4  =          2.06615
V( 46) =  V4   =        201.65057
V( 47) = BET4  =          0.19082
V( 48) = ALF5  =          0.19082
V( 49) = EFA4  =          0.00229
V( 50) = POW2  =          0.29126
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V(51)	=	P5	=	9.14639
V(52)	=	T5	=	722.31396
V(53)	=	RHO5	=	1.79358
V(54)	=	V5	=	520.74292
V(55)	=	CP3	=	2709.78857
V(56)	=	KG3	=	1.35233
V(57)	=	S-R3	=	0.13131
V(58)	=	S-N3	=	0.16165
V(59)	=	EFF3	=	0.85791
V(60)	=	VAX3	=	175.18066
V(61)	=	P6	=	6.46630
V(62)	=	PO7	=	6.67799
V(63)	=	T6	=	678.06128
V(64)	=	TO7	=	683.84497
V(65)	=	RHO6	=	1.35078
V(66)	=	V6	=	177.04234
V(67)	=	BET6	=	-0.14515
V(68)	=	ALF7	=	-0.14515
V(69)	=	EFA6	=	0.00398
V(70)	=	POW3	=	0.22848
V(71)	=	PEXD	=	6.62783
V(72)	=	TEXD	=	682.47412
V(73)	=	RHOX	=	1.37557
V(74)	=	VEXD	=	85.39653
V(75)	=	PTHT	=	5.62490
V(76)	=	TTHT	=	579.20068
V(77)	=	RHOT	=	0.37836
V(78)	=	VTHT	=	746.10352
V(79)	=	CPEX	=	2659.82422
V(80)	=	KGEX	=	1.36134
V(81)	=	ATHT	=	0.00337

VARIABLE NUMBER AND ITS FINAL VALUE

THESE VALUES ARE FOR AN ALTERNATOR OUTPUT OF 0.40 MW

VARIABLE	VALUE(SI)	VALUE(BRITISH)
V(1) = POW =	0.46784 MW	627.37939 HP
V(2) = MFLO =	0.47272 KG/SEC	1.04217 LBM/SEC
V(3) = MFLX =	9.32930 KG/SEC-SQ.M	1.91079 LBM/SEC-SQ.FT
V(4) = PHI =	0.75766	0.75766
V(5) = XNH3 =	0.08788	0.08788
V(6) = XN2 =	0.31869	0.31869
V(7) = XH2 =	0.59343	0.59343
V(8) = MWT =	11.62144 KG/MOLE	11.62144 LBM/MOLE
V(9) = P1 =	13.92802 BARS	202.00893 PSIA
V(10) = P01 =	23.30045 BARS	337.94434 PSIA
V(11) = T1 =	856.38135 DEG K	1541.48560 DEG R
V(12) = T01 =	1004.46631 DEG K	1808.03857 DEG R
V(13) = RHO1 =	2.27331 KG/CU.M	0.14190 LBM/CU.FT
V(14) = V1 =	908.05420 M/SEC	2979.18066 FT/SEC
V(15) = CP1 =	2784.08521 J/KG-DEG K	0.66541 BTU/LBM-DEG R
V(16) = KG1 =	1.34584	1.34584
V(17) = S-R1 =	0.24222	0.24222
V(18) = S-N1 =	0.14909	0.14909
V(19) = EFF1 =	0.82710	0.82710
V(20) = VAX1 =	251.64078 M/SEC	825.59302 FT/SEC
V(21) = P2 =	9.88056 BARS	143.30545 PSIA
V(22) = P03 =	10.41240 BARS	151.01915 PSIA
V(23) = T2 =	837.55127 DEG K	1507.59155 DEG R
V(24) = T03 =	849.13599 DEG K	1528.44409 DEG R
V(25) = RHO2 =	1.64895 KG/CU.M	0.10293 LBM/CU.FT
V(26) = V2 =	253.98177 M/SEC	833.27344 FT/SEC
V(27) = BET2 =	1.03000 RADIANS	59.01897 DEGREES
V(28) = ALF3 =	-0.13588 RADIANS	-7.78581 DEGREES
V(29) = EFA2 =	0.00113 SQ.M	0.01215 SQ.FT
V(30) = POWI =	0.20443 MW	274.14478 HP
V(31) = P3 =	7.95697 BARS	115.40613 PSIA
V(32) = T3 =	785.77026 DEG K	1414.38574 DEG R
V(33) = RHO3 =	1.41543 KG/CU.M	0.08835 LBM/CU.FT
V(34) = V3 =	589.02563 M/SEC	1932.49878 FT/SEC
V(35) = CP2 =	2737.67871 J/KG-DEG K	0.65432 BTU/LBM-DEG R
V(36) = KG2 =	1.35377	1.35377
V(37) = S-R2 =	0.16186	0.16186
V(38) = S-N2 =	0.13204	0.13204
V(39) = EFF2 =	0.85725	0.85725
V(40) = VAX2 =	198.15137 M/SEC	650.10278 FT/SEC
V(41) = P4 =	5.29283 BARS	76.76602 PSIA
V(42) = P05 =	5.49942 BARS	79.76234 PSIA
V(43) = T4 =	729.84863 DEG K	1313.72681 DEG R
V(44) = T05 =	737.29297 DEG K	1327.12671 DEG R
V(45) = RHO4 =	1.01366 KG/CU.M	0.06327 LBM/CU.FT
V(46) = V4 =	201.89430 M/SEC	662.38281 FT/SEC
V(47) = BET4 =	0.19286 RADIANS	11.05066 DEGREES
V(48) = ALF5 =	0.19286 RADIANS	11.05066 DEGREES
V(49) = EFA4 =	0.00231 SQ.M	0.02486 SQ.FT

V(50) =	POW2 =	0.14474	MW	194.10316	HP
V(51) =	P5 =	4.26603	BARS	61.87350	PSIA
V(52) =	T5 =	684.82446	DEG K	1232.68335	DEG R
V(53) =	RHO5 =	0.87073	KG/CU.M	0.05435	LBM/CU.FT
V(54) =	V5 =	532.26147	M/SEC	1746.26465	FT/SEC
V(55) =	CP3 =	2699.73169	J/KG-DEG K	0.64525	BTU/LBM-DEG R
V(56) =	KG3 =	1.36054		1.36054	
V(57) =	S-R3 =	0.13637		0.13637	
V(58) =	S-N3 =	0.16186		0.16186	
V(59) =	EFF3 =	0.85595		0.85595	
V(60) =	VAX3 =	179.05553	M/SEC	587.45239	FT/SEC
V(61) =	P6 =	2.91084	BARS	42.21815	PSIA
V(62) =	P07 =	3.01371	BARS	43.71017	PSIA
V(63) =	T6 =	638.33423	DEG K	1149.00098	DEG R
V(64) =	T07 =	644.31201	DEG K	1159.76099	DEG R
V(65) =	RHO6 =	0.63739	KG/CU.M	0.03979	LBM/CU.FT
V(66) =	V6 =	179.66287	M/SEC	589.44507	FT/SEC
V(67) =	BET6 =	-0.08225	RADIANS	-4.71290	DEGREES
V(68) =	ALF7 =	-0.08225	RADIANS	-4.71290	DEGREES
V(69) =	EFA6 =	0.00413	SQ.M	0.04443	SQ.FT
V(70) =	POW3 =	0.11866	MW	159.13138	HP
V(71) =	PEXO =	2.98756	BARS	43.33090	PSIA
V(72) =	TEXO =	642.79736	DEG K	1157.03467	DEG R
V(73) =	RHOX =	0.64965	KG/CU.M	0.04055	LBM/CU.FT
V(74) =	VEXO =	89.72345	M/SEC	294.36816	FT/SEC
V(75) =	PTHT =	2.52873	BARS	36.67613	PSIA
V(76) =	TTHT =	544.07642	DEG K	979.33691	DEG R
V(77) =	RHOT =	0.18210	KG/CU.M	0.01137	LBM/CU.FT
V(78) =	VTHT =	729.84009	M/SEC	2394.48853	FT/SEC
V(79) =	CPEX =	2657.07178	J/KG-DEG K	0.63506	BTU/LBM-DEG R
V(80)=	KGEX =	1.36846		1.36846	
V(81)=	ATHT =	0.00356	SQ.M	0.03829	SQ.FT

APPENDIX C

The particular input formats employed in this program are explained at the beginning of APPENDIX B. Example data cards for a 2.0-mw, three-stage turbine system follow:

Data Card Number	Column Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		8	1																	
2	.	0	1																2	0

	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
3	2.4	2.4	47.4	0.66	0.13	0.31	0.56	12.0
4	74.5	124.	964.	1120.	11.2	939.	2824.	1.32
5	0.24	0.15	0.82	260.0	54.4	57.2	950.	962.
6	8.29	262.	1.03	-0.13	0.001	1.07	44.8	899.
7	7.2	588.6	2774.	1.33	0.16	0.13	0.86	198.
8	31.1	32.2	844.6	851.9	5.33	201.7	0.19	0.19
9	0.002	0.735	26.3	806.6	4.7	499.5	2750.	1.33
10	0.12	0.16	0.86	168.	19.8	20.4	767.	772.
11	3.7	74.1	-0.26	-0.26	0.004	0.53	20.2	771.
12	3.8	78.0	17.2	658.	1.00	782.	2682.	1.35
13	0.003							

	1-4	5-8	9-12	13-16	17-20	21-24...	..77-80
14	POW	MFLO	MFLX	PHI	XNH3	...	VAX1
15	P2	PO3	T2	TO3	RHO2	...	VAX2
16	P4	PO5	T4	TO5	RHO4	...	VAX3
17	P6	PO7	T6	TO7	RHO6	...	KGEX
18	ATHT						